THE

SOIL AND CROP SCIENCE

SOCIETY OF FLORIDA

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Eighteenth Annual Meeting of the Society
Soreno Hotel
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December 1, 2, and 3, 1958

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ACKNOWLEDGMENTS

The Executive Committee is pleased to take this opportunity to thank the Management of Soreno Hotel in St. Petersburg for the obvious effort they made at all times for the comfort and care of the meetings of the Society and its members. Without doubt the advance notice and information on accomodations sent out by them to each member of the Society was a definite factor in the advance registration for the meeting which was by far the heaviest yet experienced.

Particular gratitude is expressed to Provost Fifield, Director Beckenbach and Dean Brooker for their presence and for the fine part they and a number of their staff took in all parts of the meeting, particularly in the new effort at devoting a very substantial part of the subject matter of some of the sessions to problems which we here in Florida hold in common with our good friends in Latin America.

Difficulty is found, too, in adequately expressing our thanks to Dr. R. A. Allee and Dr. Frederick Hardy from the Inter-American Institute of Agricultural Sciences in Turrialba, Costa Rica, and the resident counselor of all Latin American students on the campus of the University of Florida for their fine part in our effort at making our friends to the South feel that a great many of their Soil and Crop problems are broadly identical to ours and that we are more than anxious to work with them in their solution.

In his remarkably fine after-dinner address for which we are so grateful to Dr. J. J. Ochse, we were given a clear view not only of the very great importance of an all-hemispheric program in agriculture to the United States but also of the ever-closer association the agricultural development of Southeastern Asia is certain to have with it. The deep sincerity of his address could only come from a very long experience in both great areas coupled with a very trying one in the latter.

Too, we must not fail to recognize the long distance traveled by Dr. Armand Bes and his associate, Mr. Luis Fontana, of Ibicatu, in the State of Sao Paulo, Brazil, especially to attend these meetings; also Dr. Henry Schneider and Mr. Gordon Mackie of James Mackie and Sons, Belfast, Mr. Emilian Bobkowicz of Montreal, Mr. Joe Dryer and associates from Cuba, and Mr. Renan Manzanilla, Merida, Yucatan, Mexico, all for the opportunity of not only hearing a wide variety of papers that were presented but to discuss problems of mutual interest in the field of natural and other fibers with members of USDA and State Workers as well as Mr. George F. Quimby, Secretary-Treasurer of the Soft Fiber Manufacturers Institute, Mr. E. S. Boote, Vice President, Ludlow Mfg. Company, Dr. Thomas E. Chambers of Chicago, widely known consultant on the industrial use of natural fibers, J. J. Romeo, Fiber Division, General Services Administration, Washington, D. C., and others.

Most particularly does the Committee want to express the honor it feels in dedicating this volume of the Proceedings to the life and work of Dr. Harold Mowry, the complete devotion of whose whole life to the cause of Florida agriculture can not be set forth adequately either here or elsewhere in ordinary print.

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HAROLD MOWRY

DEDICATION

Biographical Sketch—Harold Mowry

Born at Valley Falls, Kansas, 1894, Mr. Mowry attended Campbell College at Holton, Kansas, and received the B.S.A. degree and the M.S.A. degree from the University of Florida.

Mr. Mowry joined the Florida Agricultural Experiment Station Staff October 1, 1922, as Assistant Horticulturist, following six years as citrus canker, nursery and quarantine inspector with the State Plant Board. He returned to the Plant Board in 1929 where he played an important role in the eradication of the Mediterranean fruit fly from Florida citrus groves. He returned to the Experiment Station and in 1930 was made Associate Horticulturist and in 1932 Horticulturist.

Mr. Mowry was named Assistant Director, Research, Florida Agricultural Experiment Stations in 1938 and became Director on November 1, 1943. He retired from this office on January 31, 1950. His tenure as Director was marked by material increases in research staff, physical facilities, scope of investigations and annual appropriations for the Agricultural Experiment Stations.

In 1951, Mr. Mowry went to San Jose, Costa Rica, as consulting director to that country's Minister of Agriculture under an appointment from the United States Department of Agriculture. Later, he became chief of mission and directed the work of University personnel assigned to Costa Rica under the agreement of *Servicio Tecnico Interamericano Agricola*. While in Costa Rica he aided the agriculture of the country materially by demonstrating the value of minor elements in the nutrition of the coffee plant. This resulted in increased coffee yields and subsequent higher returns for the growers. For his outstanding contributions to its agriculture, Costa Rica awarded him a medal de merito and scroll in appreciation of his services.

Mr. Mowrey's contributions to Florida's agriculture were numerous and outstanding. He made the initial findings as to the value and need of zinc for plant growth on mineral soils of Florida. He demonstrated the symbiotic nitrogen fixation in the roots of the Australian pine, and played a leading role in the development of the tung oil industry in the state and the South. As already pointed out, he participated in the campaigns which eradicated citrus canker and the 1929 Mediterranean fruit fly infestation from Florida. He received the distinguished service award of the Florida Vegetable Committee in 1947.

In planning the 1958 annual meeting of the Society, it was a strong hope of the Executive Committee that it would be able to have Mr. Mowry appear on that portion of the program dealing with Inter-American Agricultural Relationships. Unfortunately, Mr. Mowry was stricken with a heart attack just as he completed his seventh year of advisory work in Costa Rica. Following hospitalization in Washington, he returned to Gainesville in March, and on November 10, 1958 was admitted to the University Teaching Hospital where he passed away just twenty days before the meetings convened. We are justly proud to dedicate this Volume of the Proceedings to Mr. Harold Mowry whose life was devoted to agricultural research.

The Economic Importance of Western Hemisphere Agriculture to the U. S. A.

J. J. OCHSE*

Mr. Chairman; Ladies and Gentlemen:

Thank you very much for your nice introduction. I am honored by your invitation to talk at this Eighteenth Annual Meeting of the Soil and Crop Science Society of Florida on the economic importance of Western Hemisphere Agriculture to the U. S. A. This approach, however, is of exactly the same economic importance to the Eastern Hemisphere, and it is my privilege tonight in trying to answer the question, "Why".

For this answer I have to go back to the period of great development of the cultivation of raw materials in South Eastern Asia before World War II. A period in which the Western World had no clear and far sighted view of the complexities of Asiatic problems.

For a good understanding we must divide that part of the world into different sections. First, the Moslem countries in the Middle East, and the Russian part in the North.

Three Asiatic powers: India, China and Japan; and seven smaller but very important economic countries: Ceylon, Burma, Siam, Indo-China, Malaya, Indonesia and the Philippines. Those seven countries with a population of about 150 million had an export figure before the war nearly twice as much as India and China with over 1000 million people.

The production of important raw materials was:

1.5 million tons of copra
950,000 tons of rubber
100 million pounds of tea
275,000 tons of palm oil
55,000 tons of pepper, besides large quantities of different fibers, coffee, cocoa, and a tremendous amount of forest products, like tannins, resins, and so on.

About half of the above named quantities came from European managed estates, backed by very efficiently operated experiment stations, but the other half and in many cases much more than that came from small holders. The economic importance of such a cash crop income is not difficult to understand. It brings a great part of

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the population on a higher buying power level which in itself is of fundamental national value.

Then all of a sudden the war broke out and the slogan, "Asia for the Asiatics," was brought into the picture.

The white race as a whole had passed the line of no return as a result of the fact that NOBODY IN THE WORLD IN THE LONG RUN WILL ACCEPT BEING AGGRIEVED AND UNDER-ESTIMATED BECAUSE HE HAS ANOTHER COLOR OR THINKS DIFFERENTLY, WHICH WAY OF ACTING IS, AFTER ALL, NOTHING ELSE IN OUR SUBCONSCIOUS BUT AN EXPRESSION OF FEAR. On top of that, the revolution in China broke loose and will result in a unification of that great country after forty centuries of wars. Indonesia became independent and broke off all connections with the West after 300 years of cooperation, followed by, or together with, other countries in South Eastern Asia.

The result will be that within the next 25 years South Eastern Asia, with a tremendous population, will be on the world market for raw materials produced in the seven above named countries on a scale as never before dreamed of.

Wages will go up, and after years of struggle, the final picture will show an improved Asiatic way of life and an industrial development. By that time there will exist the possibility of a greater demand for strategic and essential raw materials in the Americas unless we will be able to set the sails by the wind when the wind is going to change. Due to this unexpected change of the wind, greater activities in the cultivation of raw materials will become a necessity. If there ever has been a time for the American tropics to listen to the structural changes of South Eastern Asia, then it is now.

An economic development in tropical agriculture is the program that is timely for the American tropics. Large capital investment is needed to start estate cultivation, followed by the development of small diversified agriculture in favor of a stable economy of the countries that are involved in this inevitable process.

The final conclusion of this introduction is that a CASH CROP program is of the utmost importance for the economy of the Western Hemisphere, as well as for the industry in the United States. Without large capital investment, however, it is impossible to develop such a program. After establishment of nuclei of cultivation of raw materials, that action will be followed rather rapidly by local farmers, which can be noticed already in several parts of the Western Hemisphere with the coffee cultivation in Colombia and in many Central American countries, with sisal in Mexico and Costa Rica, with cocoa on the Atlantic side of Costa Rica, and others.

Examples of successful operation are the activities of the United Fruit Company in the American tropics with banana cultivation, manila hemp, oilpalm and cocoa, followed by cooperation with local farmers like in Ecuador and other places. The only support the small farmer needs is that of a credit organization.

The development of other CASH-CROP nuclei like that of rubber, more hard and soft fibers, vegetable fats and oils, medicinal plants and others will offer more possibilities.

Food production makes the local farmer self sufficient for his daily existance which is extremely important, but that offers little else. The needed surplus is nearly always supplied in the tropics by the sale of agricultural products for the world market, so called staple products.

It is the CASH-CROP product which allows the diversified farmer to come to a higher standard of living. The great advantage in the cultivation of perennials is that the products can be stored for some time, and the plants can even be neglected for some time without harmful consequences during a drop in price or as a result of wrong distribution. With the cultivation of annuals in the tropics even on a small scale it is always the fight against the weed, which is many times lost by the farmer unless his property is large enough for mechanical cultivation and he can get the credit to bring his farm on that level and has basic training and education to understand what gocd meaning extension officers advise him to do.

So long as his property is within the reach of family exploitation and he has next to his food crops some acreage with perennials for the production of raw materials he has a sovereign remedy against great fluctuations of the economic structure because he has not put all his eggs in one basket.

He doesn't need to spend 80-90 percent of his income for food, he receives cash for other purposes to raise his economic level and he is not open to COMMUNISTIC propaganda since he has something to lose.

It is not difficult to calculate the value of: 500,000 tons of copra from the Philippine Islands produced mainly by small farmers. The same counts for 350,000 tons of copra from Indonesia, for 200,000 tons of rubber from Malaya, for 200,000 tons of rubber from Indonesia, for 1.5 million tons of Manila hemp from the Philippines, for 96% of the world production of pepper and for many others.

That can be developed in the Western Hemisphere just as well. During the period of extreme low wages and very low cost of production in many countries of production of raw materials in South Eastern Asia before the war, the cultivation of such raw materials was not very attractive in the American tropics but that picture has changed since the end of World War II.

Moreover, the conditions of soil and climate in many parts of Central and South America are very much in favor of such a development.

What is needed now is a program of cooperation between different countries in Central and South America and investment corporations in the United States. Countries with great possibilities are Brazil, Venezuela, Colombia, Peru, Ecuador and all Central American countries. Such a program, however, has to be produced not as Point Four activity, but based on scientific research and one of the items in which the SOIL AND CROP SCIENCE SOCIETY OF FLORIDA can play an important role by making a sub-division for the tropics. This is of fundamental importance.

Practically every top soil scientist in the world like Russell, Vageler, Pendleton, Mohr and many others have pointed out in one way or another that 75% of the failures in tropical agriculture has been

the result of a *wrong decision on soil and climate.* Tropical soils in general are not so rich as many still believe. By developing a subdivision for the tropics, the organization of which I am the guest tonight will contribute very much to the development of a CASH-CROP program for the American tropics.

In close cooperation with scientific institutions like the Inter-American Institute of Agricultural Sciences in Turrialba (Costa Rica) the coffee experiment station in Chinchina in Colombia, the agriculture institute in Belem in Brazil, the experiment station in Maracay in Venezuela, the Imperial College of Tropical Agriculture in Trinidad, the University for the West Indies in Jamaica and with many others, can be established the foundation for a cash-crop development for the American tropics.

There is no time and place any longer for playing to the gallery programs. What is needed is encouragement of private capital investment for the American tropics for the benefit of both parties, the Western Hemisphere and the United States. I quote Benjamin Franklin where he says: We must all hang together, or assuredly we shall hang separately.

INTER-AMERICAN AGRICULTURAL RELATIONSHIPS

Florida's Responsibility in Inter-American Agricultural Development

Willard M. Fifield*

We have all heard criticism from some of our fellow citizens about the United States giving so much foreign aid, when our home front suffers as a result. I am convinced that a good part of this criticism comes from those who are not fully aware of all the facts. Typical of the comments is the statement a little boy in school wrote on his examination: "The principal U. S. export is U. S. money." I am no authority on the matter of our total foreign aid policy, and make no pretense of defending all aspects of its scope. In the area of technical aid in agriculture, however, I believe firmly that we are on the right track.

The subject for present discussion is Florida's responsibility in Inter-American Agricultural Development. This brings the technical aid proposition right to our own doorstep. In doing this, however, it seems important to emphasize our obligations to many countries, in all parts of the world. Let's review a few facts concerning early North American agriculture.

Since the landing of the Mayflower *we* have received agricultural assistance from other countries. In the early days grains, such as rye, barley, oats and buckwheat were brought in from Europe. From Rhode Island to Georgia farmers experimented with these crops on patches of cleared land. These bread grains were established here as their adaptability was proven for our varying soil and climate. Meanwhile, native grasses—wild rye and broomstraw—proved too inadequate as winter forages for imported livestock. Again the colonists looked to their homelands and introduced red and white clover, timothy and bluegrass.

Time moved on and this agricultural borrowing continued. Sugarcane was introduced to the southern colonies from the Dominican Republic in 1751. Fifty years later hardy Siberian wheat was imported to withstand severe winters in the northern states. The more mild-climate Italian varieties were found to do well farther south.

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As our United States Ambassadors went abroad, they sent back plants and breeding animals. Barbary sheep were sent from Tunis in 1801 to improve the breed in this country. American naval officers collected seed from ports of call around the world. In 1839 Congress appropriated $1,000 to the United States Patent Commissioner to distribute these seeds to farmers, and to collect facts and figures to aid them in growing and selling their crops. With this small sum, Federal aid to agriculture was born. New ideas and new crops were brought to us by immigrants from other countries. We borrowed heavily from the experience of others. And I use the term *borrowed* advisedly.

The foundation of a strong United States agricultural economy has been built through technical cooperation, so how can we justifiably complain about returning aid for that received?

With improved crops, methods of soil management, and the development of improved farming equipment, we no longer face food shortages. In fact, we are able to share our surpluses with other countries. Our market has become a world market.

Wait a minute, you say. Yes, we borrowed all these things from other countries, but their governments didn't come in here and give them to us—we went out after them. There is a difference you say, and I'll agree. Yet somehow I am reminded of some of the things in science and literature I was taught back in high school and college. From whence came American science, literature, music, law and even religion? More of this in a moment.

In 1862 President Abraham Lincoln signed the Organic Act creating what is now the United States Department of Agriculture. During the same year he signed the First Morrill Act, providing for Land-Grant Colleges. Nothing like this had ever been done by a government before. Common people could now be afforded a college education. The federal and state agricultural activities were brought closer together in 1887 with the passage of the Hatch Act, which through matching Federal funds established a nation-wide system of state agricultural experiment stations. This Federal-State cooperation was further strengthened in 1914 when Congress passed the Smith-Lever Act, establishing cooperative extension work. This Land-Grant system afforded opportunities no other country enjoyed.

By the turn of the century, United States scientists were traveling the world over collecting foreign plants and rare seed varieties to be grown in this country. My experience at our Subtropical Experiment Station gave me a first-hand insight into what some of these explorations have meant to Florida. The name David Fairchild, whom I was privileged to know personally, ranks impressively with that of Wilson Popenoe, H. Harold Hume and Harold Mowry among the great horticulturists who have contributed to Florida's economy. When one considers that the only fruit today grown commercially in this state and native to Florida is the blueberry, one understands better our obligations to others.

The Washington navel orange came from Brazil; the Meyer lemon and other citrus from China; avocados from Latin America; mangoes from the orient. Our late-blight resistance in potatoes and tomatoes

came also from Latin America. Improvement of many domestic plants was accomplished by crossing and recrossing native plants with varieties from elsewhere.

When our nation, and our *state*, were young, plants, seeds, breeding animals and ideas came in large measure from other countries. But now that, at least in our eyes, we are mature scientifically, we *still* are borrowing. Species and strains of disease resistance, and quality varieties *still* are sought from abroad. Since modern communications have brought our neighbors closer, we mutually are aware of devastating pests which could appear almost overnight to cause economic havoc, and we are cooperatively studying control measures.

We in Florida have close ties with our neighbors in Latin America. Due to the similarity in soil and climate, we have found many of our problems are similar.

Approximately 90% of the vegetable seeds now imported into Latin America come from the United States. A tremendous quantity of ornamentals for propagation come to us from them. We in Florida ship them millions of day-old chicks and hatching eggs. Latin America is a major market for Florida's purebred cattle and swine.

Florida's responsibility in Inter-American Agricultural Development takes on many forms. Our greatest contribution could be to educate our own people on the facts, and create a sense of feeling that what we do to help others will help ourselves. I personally have acquired a more altruistic motive, but I am not asking others to share it. It is not necessary. There are ample materialistic motives.

Agricultural products exported to and imported from Latin America are becoming more and more significant. Latin America is one of the most important export markets for the United States. More than one-quarter of this country's total exports of such commodities as rice, machinery, automobiles and parts, chemicals and textiles are shipped to Latin America. In return, that region is the main source of United States imports of coffee, sugar and bananas.

For several years the University of Florida has had an agreement with the International Cooperation Administration in which we in agriculture provide training for foreign participants. This commonly is known as the Point Four program. My office coordinates this program in agriculture for the University. We have processed hundreds of participants from all over the world since the beginning of this agreement. The majority come from Latin America. Some of these participants enroll at the University for one or more semesters, while many others make shorter visits to our various departments and branch stations, and to our Extension Service facilities on and off campus. Our responsibilities in planning itineraries, making proper contacts and arranging programs suitable to their needs are time-consuming, but we believe worthwhile. The cooperation of many people, within and outside the organization, has been necessary to keep the program successful.

These visitors come here to learn of our proven methods and our administrative policies, and to get acquainted with our personnel. Such personal friendships have enabled follow-up relations of inestimable value for both sides.

The University of Florida also has a specific ICA college contract with STICA of Costa Rica. Under this contract we provide technical agricultural research exchange between members of our own staff and staff members of the Ministry of Agriculture and Industry of Costa Rica. We feel this cooperative venture has been most worthwhile for us, and there is evidence of mutual satisfaction on the part of our Costa Rican colleagues. This is a specific Florida undertaking in Latin American agriculture.

Now let's get back for a moment to this whole matter of United States agricultural aid to Latin America. We have reviewed our early heritage and benefits derived. We acknowledge them as a matter of course. But we of this particular United States generation, while historically aware of our blessings, somehow have come to feel a little smug in our accomplishments. Why, we say to ourselves, if we have come to these great blessings, why can't others? We are a nation of pioneers, and our economy is based upon the great freedoms, among which is the freedom of enterprise. You and I in this room today have never known any other system. We have enjoyed other blessings, too.

Consider if you will that in Mexico the mountainous nature of the terrain makes cultivation of more than half the country impossible. Yet I have seen oranges there, and cotton, which are not surpassed quality-wise in our country. The tropical soils there which have sufficient moisture are tremendously fertile, but the presence of tropical diseases and insects has retarded development.

In South America, land with a slope of less than eight percent which may be readily and safely cultivated is extremely scarce, except in the plateaus and plains of Argentina and the Amazon Basin. Unfortunately many of these level areas are handicapped by extremes of either too much or too little precipitation.

During the past decade the per capita food supply inside Latin America has been increased, but extreme deficiencies in diet continue to characterize the area. The 2½ per cent per year growth in population in Latin America is the highest in the world and it exerts steady pressure upon the limited agricultural productive capacity.

In considering these and many other features of Latin American agriculture, it is essential to remember that these people do not have, in many instances, the extensive background of investigation upon which have been built the great agricultural industries of the United States or of Europe. Let us remember, too, that they have been and are still confronted with socio-economic-political problems which are exceedingly difficult for us to comprehend. But let us also remember that our own forefathers were confronted with extremely difficult problems. The problems they solved seem simple to us, now, but perhaps it's because we *inherited* the solutions.

As mentioned earlier, there is criticism of our technical aid to other countries. Perhaps some of this is based on our American free-enterprise philosophy that it is a mistake to spend money helping competitors. Let's remember though that in this foreign aid deal there is another aspect. If we can help another nation improve its economic status, that nation's potential as a good customer is correspondingly increased. This is just good business, and has no par-

ticular relation to the Golden Rule. We have other interests. We are proud of our system of government, and of our system of enterprise. Yet we know these things are threatened today. You have heard this so much it's becoming trite, yet underneath you know it's not trite—it's true.

Because of our total heritage, we enjoy certain unique blessings. *We* didn't carve them out, you and I. We believe in our way of life, but sincerely, not for ourselves alone. We have been brought up in hope, borne of knowledge and of opportunity. Can we not afford to share these things with our neighbors?

FLORIDA'S CONTRIBUTIONS TO AGRONOMIC DEVELOPMENT IN CENTRAL AMERICA

1. Soils Research in Costa Rica

GAYLORD M. VOLK*

The writer was assigned to Costa Rica to act as consultant in the planning and activation of a STICA laboratory to be located on the campus of the University of Costa Rica. This laboratory was intended to handle plant and soil analysis, both for research and extension, in STICA and certain divisions of the Ministry of Agriculture. The laboratory building was finally completed and put in operation in August of 1957.

Prior to the establishment of the new STICA laboratory a limited amount of laboratory investigation was carried out with very inadequate facilities in the old Ministry of Agriculture building. The laboratory operated under the Laboratory Project, headed by Dr. Lino Vicarioli. Ing. Gil Chaverri was in immediate charge of the laboratory with a staff of ten to twelve professional and non-professional personnel. Of necessity, certain methods of analysis were adapted to simple routines, but purchase of equipment, including a Perkin-Elmer flame photometer, permitted considerable improvement. Of the several laboratory projects underway in July of 1956, the ones receiving the most attention were: complete mineral analysis of coffee leaves collected systematically by season and age; the analysis of coffee leaves showing symptoms of abnormality; and extension service analysis of soils and leaves as an aid in making recommendations to individual growers.

The results of these early investigations should be given considerable credit for the rapid advance in practical use of fertilizers and sprays, both with respect to major and secondary elements. A fairly complete and adequate soil survey of the Meseta Central, the major coffee growing district, was of inestimable help in initial research and the application of research findings (2, 6). These soil surveys probably should be classed as detailed reconnaisance, the type most practical for first intensive effort in any otherwise nonsurveyed area. This type of survey catalogues and describes the significant variations that exist, allowing research to proceed on an intelligent basis without the long delay usually associated with completion of large areas by detailed inventory surveys.

Early work by the laboratory resulted in selection of the fourth or fifth leaf from the end of the coffee branch as the one to be collected for analysis. Results of this work and that of the Coffee Project along related lines have been published (1, 3, 4, 5). Correlation of

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leaf analysis with symptoms of abnormality is acceptable with the majority of elements if the deficiency or toxicity is extreme, but much is to be desired in the use of this tool as a service to growers. Soil analysis was found to be of the same general category as a service tool. Analysis for pH and exchangeable bases can be justified as a service, although even with these soils of relatively high base exchange capacity the large majority of the soils fall into the indefinite intermediate range where general recommendations for the soil group in general must be followed. There was some indication that pH is not an adequate criterion of calcium supply with certain soils. A relatively high pH was maintained probably by partial saturation of the exchange with organic constituents or aluminum. Very active forms of calcium such as calcium nitrate or calcium hydrate were suggested for these areas.

Analysis for available phosphorus was completely misleading in most instances for the various soils, even though a range of extractants were used. Work on methods of estimation of this element is needed. Coffee has remarkable ability to extract adequate phosphorus from soils, but apparently this is not true for most agronomic crops. Studies on phosphorus fertilization present a real challenge for the future. Phosphorus, along with minor elements, probably hold the answer to the poor productivity of certain agronomic crops.

THE NEW LABORATORY

The new laboratory building contains about 6000 square feet of space in two floors (Figure 1). The first is devoted to sample acceptance, preparation, and general storage, with one large room reserved for library and conference purposes or future expansion. The second floor is used entirely for laboratories with the exception of the administrative office. Certain new furniture including fume hoods and sinks were obtained for the new building, but the majority of the desks and laboratory equipment were transferred from the old laboratory. This was supplemented by equipment obtained from the USDA rubber laboratory when this project was closed out in Costa Rica. Further needs in the way of furniture probably are being met by local construction which is relatively economical as compared to foreign purchase. Certain heavy equipment, including a macro kjeldahl, were to be supplied from a grant by a private agency in this country.

SUGGESTED LABORATORY STUDIES

Laboratory studies initiated by the writer while on assignment included the following.

1—A study of factors involved in the efficiency of conversion of urea to ammonia and nitrate.

2—The effect of fertilizer anions in excess of plant requirements on the leaching losses of nutrient bases.

3—Factors determining the severity of biuret toxicity symptoms of coffee.

Figure 1.—The new STICA laboratory, constructed on the campus of the University of Costa Rica, San Jose. 1957.

4–Total phosphorus and potassium contents of various representative soils, and relative solubility of these two elements in various extractants.

5–Correlation of starch storage cycle with coffee cherry drop and timing of nitrogen and potassium fertilization.

Progress on the various studies was very much limited by inadequate facilities of the old laboratory, by previous committment of personnel to the completion of work already underway, and the confusion of moving and reestablishment in the new laboratory. Work on the first study was adequate to indicate that no major problem existed in the conversion and utilization of urea nitrogen, a favored form because of its relatively low cost per unit of nitrogen in Costa Rica. Hydrolysis of urea to ammonia was rapid and nitrification proceeded normally except where soil pH was so low as to be limiting. The need for lime was indicated.

An excellent piece of work was done by Srta. Anna Ramoz on the

second phase involving the effect of superfluous anions on the leaching of bases. There was a very difinite indication that selection of materials to reduce the quantity of chloride and sulfate ions as much as practical in keeping with plant requirements and economy of materials would markedly reduce losses of magnesium, calcium and potassium. Loss of the first two is not a particularly important consideration in the USA where sources of calcium and magnesium bearing limestone are common. In Costa Rica dolomite is practically non-existent and transportation charges for lime very high, especially in outlying districts away from the railroad. Magnesium is deficient in many areas and is supplied by magnesium sulfate purchased abroad. The writer suggested trials with magnesium oxide a material lacking in superfluous anions and considerably more economical per unit of magnesium.

Considerable emphasis was placed on the need for lime, especially on the lateritic soils. Remarkable responses were obtained when this was included with other improved practices. Increasing the percent base saturation with calcium by liming not only improves general plant soil environment but results in greater efficiency of the more expensive bases such as potassium and magnesium. At the higher degrees of base saturation with calcium, this element is lost in preference to potassium, magnesium and ammonia, but with strongly acid soils calcium is not present to replace the more valuable bases in the leaching stream. An extensive revision of Florida Agricultural Experiment Station Bulletin 506 R on fertilizer technology was made by the writer for application to Costa Rica (7). It was translated to Spanish by Ing. Gil Chaverri R.

The existence of what appeared to be biuret toxicity symptoms on coffee was first brought to attention by the late Dr. Harold Mowry, but correlation of the symptoms with use of urea containing biuret was erratic. The writer set up laboratory pot tests in an attempt to ascertain that biuret was responsible and to determine the cause of this eratic response. Soil treatment with chemical biuret was made to young coffee plants which had been well established in clay cylinders. The plants were just starting to shoot a new flush of growth at the time the treatments were made. Symptoms on the new leaves were proportional to the quantity of biuret added (Figures 2, 3, 4). The leaves showed very slight chlorosis between the veins where treatments were low but with the heavier applications the areas between the veins became completely yellowed. With the highest treatment the leaves were yellowed and temporarily stunted. In no instance did chlorosis appear on the older leaves, indicating that toxicity symptoms could be expected to appear only if the plant was subjected to biuret when the leaves were very young. Another symptom still very apparent even six months after treatment was shortened internodes in growth which took place at the time of treatment. (Figure 5).

As the plants aged, mild symptoms disappeared and normal leaves developed, but where pronounced initial toxicity was shown the leaves still contained yellow spots or areas (Figure 5.). Even the temporarily stunted leaves grew quite rapidly after the initial shock wore off, but retained symptoms of toxicity for several weeks after

Figure 2.—Young coffee plant two months after treatment with 0.8 grams of biuret. Note the deep corrugations in the leaves and chlorosis of leaf edges and between the veins.

treatment. The importance of biuret toxicity in terms of yield was never determined, but the mere appearance of abnormality would be sufficient for a grower to discriminate against a product if he correlated it with a given material. Analysis of various products by the STICA laboratory indicated that prilled material on the market at that time carried from 1.63 to 3.38 percent biuret. This was sufficient to cause the symptoms to appear if used at the usual rate and at the time that new growth appeared. Crystal urea contained up to 0.56 percent biuret.

Laboratory studies indicated that biuret persisted in the soil for a longer period of time than did urea. Urea is hydrolyzed to ammonia in the soil within two to three days time but indications were that some biuret might persist for as much as a month after application, thus allowing an extended period during which the plant could take up the material in its original form. Toxicity symptoms due to biuret in spray materials were noted also by members of the Coffee Project.

Figure 3.—Young coffee plant two months after treatment with 1.6 grams of biuret.

Work on relative solubility and total content of phosphorus and potassium in representative soils was not very satisfactory, but this work is continuing and should throw some light on the rates of build up or depletion of these two elements under existing practices. Coffee field plots which had been under various comparative treatments for up to five years were the primary source of samples for these studies. The build-up of potassium was very evident during this period, indicating that a general reduction in application ultimately can take place.

The last study on starch reserves was started after the laboratory was transferred to its new location and as a result little progress had been made up to December of 1957. This is one of the most important of all investigations on coffee if further increase in coffee production over and above the already phenomenal response to existing practices is to be obtained. A considerable portion of the coffee cherry crop falls before harvest each year. In some years this constitutes a major portion of the crop on some areas. The coffee plant is unique

Figure 4.—Young coffee plant two months after treatment with 3.2 grams of biuret. Note that the old leaves show no symptoms of toxicity but that the young leaves are almost completely yellow.

in that it stores starch in the leaves in quantities up to 20 percent of the dry weight of the leaf. This is then depleted by cherry development and plant growth until it drops down to as low as one percent. On certain heavily loaded branches the older leaves appear to have served their function and drop before the associated cherry crop is harvested, while in others the leaves persist and continue to appear to be functioning. It is postulated that depletion of the starch in the older leaves causes them to absciss and drop, indicating too heavy a simultaneous withdrawal of the starch by the cherries and the growing branches. Subsequently part of the cherries fall because of a lack of carbohydrate to sustain continued development. If it were possible either to increase starch storage, or to time growth of new wood to a period that would be less competitive with the crop development, a greater portion of the cherries might be retained.

It is known that a high nitrogen level encourages plant growth, while a high ratio of potassium to nitrogen encourages starch storage.

Figure 5.—The same plant shown in Figure 4, only five and one-half months after treatment. Note the residue of chlorosis that still remains and the markedly shortened internodes of the top growth that resulted from the new terminal growth of Figure 4.

Changing the timing of these two elements in the fertilization cycle needs to be studied with respect to its effect on starch accumulation at certain periods and its rate of depletion during the period of maximum cherry drop.

The need of Costa Rica for technical assistance in soils research will be great for several years, but eventually should be eliminated by the program of education of Costa Rican technicians now under way both in Costa Rica and abroad. The main lack is a large backlog of experienced personnel who can draw on each other for advice and criticism as the work progresses. There is a wealth of ability, enthusiasm and energetic support of both basic and applied research, but the historical experience so common and accepted in our agricultural research organization is limited at present.

The writer wishes to express his appreciation to members of the STICA laboratory staff and of the Coffee Project for their coopera-

tive effort in the foregoing investigations, and particularly to Ing. Gil Chaverri, Ing. Victor Perez and the late Dr. Harold Mowry for their cordial assistance throughout the assignment.

BIBLIOGRAPHY

1. Chaverri R., Gil, Elemer Bornemisza S. and Francisco Chavaz S. Resultados del analysis foliar del cafeto en Costa Rica. Ministerio de Agric. E. Ind. Inf. Tech. No. 3. 1957.
2. Dondoli B., Cesar, and J. Alberto Torres M. Estudio geoagronomico de la region oriental de la Meseta Central. Boletin de Ministerio de Agric. E. Ind. 1954.
3. Perez M. L., Victor. Algunos deficiencias minerales del cafeto en Costa Rica. Ministerio de Agric. E. Ind. Inf. Tech. No. 2. 1957.
4. Perez M. L., Victor, Gil Chaverri R. and Elemer Bornemisza. Algunos aspectos del abonamiento del cafeto conboro y calcio en las conditiones de la Meseta Central de Costa Rica. Ministerio de Agric. E. Ind. Inf. Tech. No. 1. 1956.
5. Perez M. L., Victor. Labores del projecto No. 23 en el mejor amiento del cultivo del cafe. Ministerio de Agric. E. Ind. E. STICA. Inf. No. 4. 1958.
6. Vargas V., Oscar, and Jose Alberto Torres. Estudio preliminar de suelos de la Meseta Central. Ministerio de Agric. E. Ind. Bol. Tech. No. 22, 1958.
7. Volk, Gaylord M. Fertilizantes. STICA mimeo. 17 pp. 1957.

2. Costa Rican Pastures

Gordon B. Killinger*

In the early spring of 1955 it was this writer's privilege to move from Gainesville, Florida to San Jose, Costa Rica and assist Costa Rican specialists in their Agronomic Research Program, particularly with pastures and forages. My assignment was for a two year period which made it possible to conduct field experiments through two growing seasons.

Most of the agricultural research in Costa Rica is carried out by men working in the Ministry of Agriculture and Industries with some phases cooperative with the University of Costa Rica.

Pastures in Costa Rica can be classified in two groups by topography and cattle, i.e., the highland pasture used primarily for dairy cattle and the lowland pasture grazed in the large part by beef cattle. Quite naturally the species of plants grown under such varied conditions are also quite different. Tropical or warm season grasses and various Desmodium and Centrosema species are prevalent in the lowland areas whereas the more hardy semi-tropical or temperate climate species along with alfalfa, white clover, oats, barley, rye and other similar types are found at the higher elevations or on mountain slopes.

A great deal of the grass grown at the higher elevations is harvested by hand as cut forage.

Precipitation ranges from 50 to 200 inches per year, however, distribution of rainfall is not good, otherwise, pastures would be green the year round. A prolonged dry season usually starts in December and extends through May or June with little if any rainfall. That part of Costa Rica which is on the Pacific Ocean side of the mountains is the most susceptible to droughts whereas most of the area on the Atlantic Ocean side has a more continuous moisture supply with only a few days or a week or so without rainfall.

Some of the more common forage species found in Costa Rica are:

*Jaraguagrass (*Hyparrhenia rufa* (Nees) stapf)
*Molassesgrass (*Melinis minutiflora*) (Calinguero)
*Carpetgrass (*Axonopus compressus*) (Zacate amargo)
*Bermudagrass (*Cynodon dactylon*)
*Bahiagrass (*Paspalum notatum*) (Gengibrillo)
**Pangolagrass (*Digitaria decumbens*)
**Paragrass (*Panicum purpurascens*)
**Caribgrass (*Eriochloa polystachya*) (Janeiro)
***Kikuyu (*Pennisetum clandestinum*)

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*General adaptation.

**Lowland species.

***Highland species.

**Guineagrass (*Panicum maximum*)
***Imperial (*Axonopus scoparius*) (Gramalote)
*Napier (*Pennisetum purpureum*) (Gigante or Elephant)
***Orchard (*Dactylis glomerata*)
***Red Top (*Agrostis*)
***Bluegrass (*Poa paratensis*)
***Timothy (*Phleum pratensis*)

There have been 88 genera of legumes classified in Costa Rica with some of them trees. Some 27 species of Desmedium, 7 of Crotalaria, 8 of Trifolium and 14 of Phaseolus have been identified and are quite wide spread.

Tropical Kudzu and velvet beans are two legumes planted in the lowlands for grazing and hay purposes.

While in Costa Rica it was this writer's privilege to assist in developing a detailed project for forage evaluation. During the two year period, over 400 introductions of grass and legume species both seed and vegetative material were placed in several nurseries at different locations for evaluation.

New oat strains from the Florida Agricultural Experiment Station were introduced and several of these yielded over 90 bushels of grain per acre at elevations of 3,500 to 4,500 feet. Prior to this about the only successful oats were midwest varieties grown at 6,000 to 7,000 feet elevations.

Louisiana red, Pennscott red and Louisiana white and Ladino clovers were all adapted to the soil and climate at elevations of 4,000 to 8,000 feet.

Hairy indigo, buffelgrass, Pensacola bahia and Argentine bahia were found to be adapted from sea level to 1,000 feet elevation areas and showed real promise.

Sweet yellow lupines (white seed) grew well at 5,000 to 8,000 feet elevation, but appeared to be affected with virus. At this elevation potatoes and English peas were common crops and the peas seemed to have a similar virus.

Projects were developed cooperatively with the Costa Ricans and Dr. Gordon Kirk of the Range Cattle Experiment Station involving pasture fertilization and management.

Experiments during the two year period proved on most soils, limestone, nitrogen, phosphorus and potassium would greatly increase yield and improve quality of the forage.

Two mechanical pull type fertilizer spreaders were brought into Costa Rica to facilitate the spreading of limestone and fertilizers.

Both molassesgrass and Jaraguagrass gave a tremendous response to nitrogen applications of 90 to 180 pounds per manzana (1.7 acre).

Many pastures in Costa Rica were over stocked with cattle. To a point this condition was rectified by fertilization, rotational grazing and mowing of weeds and mature grass.

Total production of forage grown above an elevation of 5,000 feet was limited but still the sizeable dairy industry was largely located at such elevations. Even sugarcane was grown intensively at elevations above 3,000 feet and 20 or more months were required between

harvests. Corn grown at 6,000 to 8,000 feet elevations required 10 to 12 months to mature.

It was felt that some of these crops along with pastures would be more productive when grown below the 3,000 feet elevation. Warm climate, rainfall and transportation difficulties were obstacles in the path of changing a well developed long time system of agriculture. Improved roads, electricity and communication facilities were more available in the highland areas than in the lowlands.

All investigations carried on while in Costa Rica were cooperative between the Costa Rica personnel, STICA—International Cooperation Administration—U. S. Personnel and members of the Florida Mission.

Figure 1.—Oat Nursery on El Alto Experiment Station. Florida bred oats pro duced 94 bushels of grain per acre on this station.

Figure 2.—Jaraguagrass (*Hyperrhenia rufa*) silage produced on the El Capulin Experiment Station. Grass silage is a feed assist during the five to six month droughts experienced annually in the Guanacaste Area.

Figure 3.—Typical Herd of Range Cattle on Jaraguagrass Pasture in Costa Rica.

Figure 4.—Brahman Cattle Grazing Fertilized Jaraguagrass Pasture Plots near San Jose. Note the effect of fertilizer on grass in center with no fertilizer on left center. Nitrogen increased total forage production by 400-500 percent.

Figure 5.—Criollo Cow and Calf, Typical of Early Foundation Dairy-Beef Cattle in Costa Rica.

Figure 6. Quadrat or cage designed to protect forage from grazing and from which forage samples were collected for yield and chemical composition.

3. Animal Husbandry and Nutrition

W. G. Kirk[1]

There are many points of similarity between beef cattle production in Costa Rica and Florida. Cattle have been indigenous to both areas for over 400 years, the original stock in each country having been brought in by the Spanish conquistadors early in the 16th century. The native, or Criollo, cattle bear considerable resemblance to the Florida native cows and have made a hardy foundation stock. While there has been upgrading by means of crosses with several breeds, other factors such as climate, rainfall, feed conditions and parasites have held back general improvement. The basic problems in Costa Rica are exactly like those which confronted Florida cattlemen 15 to 20 years ago and the whole cattle picture has a very familiar look.

Costa Rica is divided lengthwise by mountain ranges which extend from the border of Nicaragua on the north to Panama on the south. These mountains, rising to elevations of 11,500 feet, give the country a variety of beauty as well as a rainfall distribution different from that of Florida. The coastal climate is much like south Florida, but the central plateau with a year-round average temperature of 75 degrees and productive volcanic soils plus ample rainfall is the bread basket of the country. The annual rainfall on the Pacific side of the mountains ranges from 40 to 80 inches and comes mostly from May to November with little rain during the other five months. On the Atlantic or eastern side, the rains are more evenly distributed throughout the year, varying from 75 to 150 inches with as much as 180 inches in several areas. This heavy precipitation poses almost as great a problem for cattle production as the dry periods on the Pacific side.

The soils of Costa Rica have considerable natural fertility but because of heavy rainfall and high temperatures there is insufficient soil nitrogen for the production of quality forage. Deficiency diseases due to lack of both major and minor mineral elements are factors in the low production of range cattle in Guanacaste and other cattle areas of the country. Production of natural grass is not a problem after the start of the rainy season in May. Grass growth is so rapid that even with overstocked ranges the cattle cannot consume all the forage. However, as the rainy season continues, flooded pastures become difficult and hazardous for the grazing cattle; and plants decrease in quality with age and leaching. With the on-set of the dry season, pastures can no longer support the same number of cattle so that the ensuing 2 to 4 month dry period may result in drastic

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[1]Vice-Director in charge, Range Cattle Station, Ona, Florida. Assisted with the development of a beef cattle research program for Costa Rica under a cooperative agreement between the Costa Rican Government and the University of Florida. Dr. Harold Mowry (deceased) and Senor Romano A. Orlich arranged inspection trips of the main beef cattle areas of Costa Rica, and Senor Adalberto Carrillo served as a guide on the necessary trips.

weight losses among all cattle and starvation and death for the less hardy.

According to the 1952 census there were 656,836 head of cattle. 120,072 swine and 81,753 horses, mules and asses in Costa Rica. The majority of the beef cattle are raised in the province of Guanacaste located on the west coast. This is the cow country of Costa Rica, made up of small and large farms and ranches complete with the necessary equipment and horses and colorful cowboys. Cattle provide the larger part of the revenue in this area and are used not only for beef but also for milk production. The Criollo cows are milked once daily and the calves allowed to run with the cows 12 hours per day. Cheese made from the milk is sold in San José and the surrounding thickly populated areas, providing ready cash for the operation of the cattle enterprise. Criollo cattle are able to reproduce and yield considerable beef under extremely unfavorable conditions and are valuable foundation animals for breeding and improved management programs. Mating Criollo cows with Brahman sires has produced hybrid vigor and retained the heat and insect tolerance necessary in an equatorial climate. Attention needs to be given to using more mature beef-type bulls, separation of young bulls from the breeding herd, castration of calves soon after birth and a controlled breeding season. Constant culling of unproductive animals can do much to upgrade most beef herds.

The city of Alajuela, in the Meseta Central, has the only public livestock market in Costa Rica where most of the livestock are sold. This market has been in operation for many years and it was only in 1956 that new facilities were put into operation. Sale of cattle at the market is either by public auction or private treaty. Direct marketing of both cattle and beef has increased with some exportation to neighboring Central and South American countries. Cattle have been driven to and from market for many years, but in recent times, with the advent of better roads, truck hauling has increased. There are many small slaughter plants but none with sufficient capacity to make the best use of by-products. Refrigeration facilities are increasing but most of the beef has to be sold immediately after slaughter and goes to markets and stores without chilling or ripening.

There is an annual increase in the number of farms on the eastern slope of the mountains, mainly in the north eastern section of the country. Many animals raised in Guanacaste province are taken to the San Carlos and adjoining areas for fattening, being sent to market as 2, 3 and 4-year-old steers weighing 1000 pounds or more. Frequently the grass-fattened cattle are comparable to U. S. Standard with some in the U. S. Good grade.

Costa Rica has many ticks and other external parasites, chief of which is "torsalo." These cause heavy losses in thriftiness of animals and in the quality of hides and are serious economic and production problems. Much progress has been made in the development of methods to control these parasites.

Better forages along with improved pasture management, deferred grazing and feed storage will take care of many feed difficulties, while good irrigation and drainage practices will make pasture lands more

productive. Many grasses and legumes have been introduced and are being tried out under a variety of conditions. Work is being continued on the forage plants that have been grown in Costa Rica for years.

Up to the present time protein concentrates and mineral constituents have not been used much because almost all of these have to be imported and the economy of the country has made the cost of these almost prohibitive. Legume plantings are doing well in many sections and will help tremendously with the protein needs. Costa Rica grows a great variety of crops and as the country develops and the population grows there should be considerable industrial waste available for processing into feeds.

Three experiment stations in Costa Rica are working on cattle breeding, feeding and management problems. The El Alto Station near San José is mainly concerned with dairy production, while the El Capulin Station, Liberia, Guanacaste, established in 1955, has become the center of beef cattle research. The Inter-American Institute of Agricultural Sciences at Turrialba, located on the Atlantic side of the mountains where there is an abundance of rain throughout the year, conducts research with both dairy and beef cattle. With these facilities coupled with natural resources and a greater interest on the part of both cattlemen and officials, the outlook for the production of beef cattle in Costa Rica is excellent.

4. Insect Control Problems In Costa Rica

L. C. Kuitert*

During 1955 I was offered and accepted an entomological appointment in Costa Rica. We arrived in San Jose in January 1956. I greatly appreciate the opportunity given me to give assistance in the planning and initiation of some investigations on the Mediterranean fruit fly.

By way of introduction, let me make a few comments about the country. Costa Rica is about one-third the size of Florida or approximately 20,000 square miles. The population passed the one million mark during my stay. Over 80 percent of the population is of Spanish descent and the religion is predominantly Roman Catholic. The main occupation is agriculture with coffee, bananas, cacao and abaca being grown specifically for export. The population is about 80 percent rural. Finally, I hope that everyone will remember this statistic, since it makes Costa Rica unique among our Latin American neighbor countries: the literacy rate is about 80 percent.

GEOGRAPHIC DESCRIPTION

The terrain is essentially mountainous with alternate steep mountains and valleys. Approximately 60 percent of the population live within the central plateau (Meseta Central) which embraces approximately 5 percent of the total land mass of the country. The central plateau is a relatively flat area about 70 by 30 kilometers in size and bounded on all sides by steep mountains. The many rivers and smaller streams have cut deep gulches and canyons so that the terrain of the plateau is mostly hilly. The few flat areas present have considerable slopes. The elevation varies from 1,360 meters (4,500 feet) at Tres Rios on the East to 760 meters (2,500 feet) at Atenas on the west. The mountain range to the east with Volcano Irazu is most imposing with an elevation of 3,482 meters (11,300 feet). The ranges to the north vary from 2,800 meters (Volcano Poas) to 2,400 meters with the ranges to the south being somewhat less imposing. The soil, of volcanic origin, is unusually fertile.

Much of Costa Rica lies within an ecological zone classified as sub-tropical humid forest type in the Atlas Estadistico de Costa Rica. Much of the country in the Atlantic watershed is classified as subtropical very humid forest type.

Precipitation on the Meseta Central ranges from 80 to 118 inches per annum, with the period of heaviest rainfall occurring from May through November. A pronounced dry season usually begins in January and extends through April. The climate is comparatively cool with a mean maximum temperature of 78.0° F. at San Jose.

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AGRICULTURAL CROPS

Bananas are the most important export crop. They are grown throughout the area with the exception of some of the higher peaks, although the main commercial areas are the Pacific and Atlantic Coastal areas. Coffee is grown for export and production is increasing. It is grown under a variety of conditions; however, commercial production is concentrated on the central plateau and adjacent areas. Citrus trees of one kind or another, with oranges dominating, are universally present in home gardens, whether in enclosed patios in cities or in remote rural areas. Other fruits commonly observed are guavas, mangoes, papayas and pineapples. Other domestic crops include cereals, sugar cane, plantains, potatoes, tobacco and a variety of vegetables and flowers. The dairy and cattle industry is sizeable and hogs and poultry are produced. I point up the specific crops to indicate that Costa Rica grows all Florida crops plus several additional tropical ones. Usually a wide variety of crops means a wide variety of insect pests and Costa Rica is no exception in this respect.

INSECT PROBLEMS

Essentially, the major insect pests encountered in Costa Rica are found in Florida. In my opinion, the two most serious insect problems plaguing the country are the "torsalo" or human warble fly and house flies. The torsalo is a serious pest of cattle, oxen, pigs, dogs, and various wild animals as well as man. This fly is known to lay its eggs on the lower side of the abdomen of several species of mosquitoes. When the mosquito visits a suitable host for a blood meal either the warmth of or contact with the host causes the eggs to hatch. The tiny larvae enter the skin of the host and about three months are required to complete larval development. Most hides and skins are ruined when the larvae penetrate through the skin and drop to the ground to pupate. Houseflies are known to be carriers of dysentery and tuberculosis. The infant mortality rate is 100 deaths per 1,000 live births and the major infant killer is dysentery. Due to the many animals, including dairy cows, oxen, horses, hogs and chickens, houseflies are never lacking for a supply of suitable breeding material. Adding to the problem is the absence of screens and poor sanitary conditions.

The agricultural insect pests can best be discussed under the crop. Essentially, the insect pests encountered in Florida are found in Costa Rica; however, the problems have not been studied extensively.

Bananas are attacked by a variety of pests, including thrips, grasshoppers, a katydid, several beetles and mites. No control measures are applied except in the commercial plantings and these are handled directly by the United Fruit Company. A variety of insects feed on coffee plants. Mealybugs feeding on the roots are serious pests in some areas. Long horned grasshoppers and leaf feeding beetles feed extensively on new growth and apparently aid in the transmission of a serious disease of coffee. Mites are serious pests of mature foliage. Corn, sugar cane and other forage crops are attacked by the southern

corn rootworm (or a close relative), wireworms, the Fall armyworm and cutworms. Hornworms, the tobacco budworm and the green peach aphid are pests of tobacco. All of the major pests of citrus, with the exception of Florida red scale, are found on citrus. These include purple scale, purple mite, two-spotted mite and rust mite. Citrus blackflies are universally present but are held in check by parasites and never were observed in serious numbers. The Mediterranean fruit fly, a recent introduction, is a serious pest of the fruit.

The vegetable crops are relatively free of insect pests. Hornworms occasionally are serious on tomatoes, thrips on onions, cabbage butterfly on cabbage, thrips on beans and aphids on a variety of vegetables. For the most part, no attempt is made to apply control measures. Good control recommendations have been worked out for thrips on onions and hornworms on tomatoes. Where effective control measures are known, they are used extensively by growers.

Fruits, including guavas, mangoes, roseapples, papayas and a variety of lesser tropical fruits are almost 100 percent infested with one of several species of fruitflies. The writer does not recall having seen a guava free of infestation. No effort is made to control these pests.

CONCLUSIONS

Biological control of many crop pests is effective in reducing several insect pests to non-economic levels. In a few instances where effective control measures are known, they are used extensively. Insect problems on a number of crops require investigation and study.

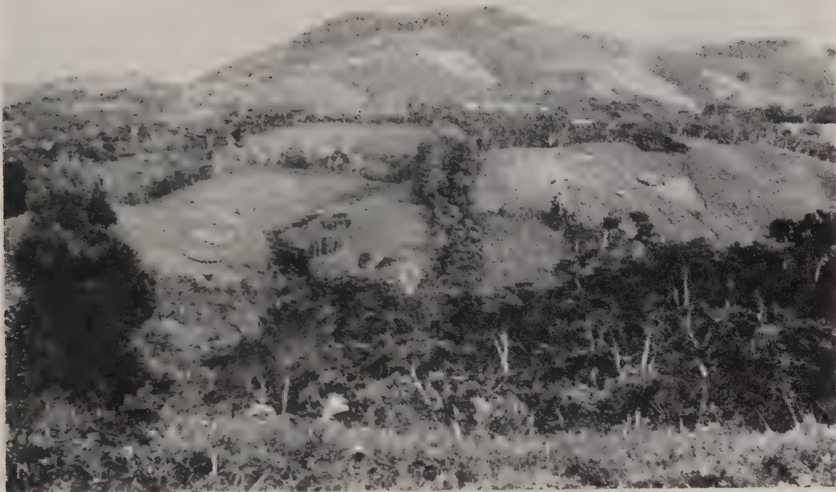

Figure 1.—In some areas, all available land is in cultivation.

Figure 2.—Dooryard citrus plantings are almost universal in Costa Rica.

Figure 3.—Entrances to numerous fincas are lined with citrus.

Figure 4.—Typical terrain of much of Costa Rica consists of shade trees interplanted with coffee and bananas.

5. Plant Diseases in Costa Rica

M. K. Corbett*

Diseases of plants have undoubtedly been recognized since the beginning of time. Man most likely recognized and knew several diseases of plants long before he acquired the art of writing. Records of plant diseases are to be found in many ancient writings, especially the bible. The causes of these diseases—rusts, blasts, mildews and blights—were unknown and usually attributed to the wrath of the various gods.

During the period of the dark ages—from the fall of the Roman Empire until the beginning of the seventeenth century—very little in the way of science and learning was accomplished or documented. It is not surprising then that during this period information concerning the nature of plant diseases is lacking.

After the dark ages a more or less general revival of interest in plant diseases occurred. However, during this period (17th century) the opinions concerning the cause of plant diseases was largely dominated by superstition and the philosophies. The 18th century brought the development of the taxonomic classification of plant diseases but their cause was attributed to the mysterious or supernatural. During this period plant disease control got its start and the theory of the autogenetic nature of disease was beginning to form. During the 19th century the work of Louis Pasteur dispensed with the theory of spontaneous generation. The pathogenic nature of fungi was becoming established and a new phase of plant pathology—the etiologic phase—came to dominate the science.

With the discovery of the pathogenic nature of the fungi the study of plant pathology became a science which today is important to the field of agriculture.

A plant disease may be conveniently defined as any appreciable departure from the normal. Diseases may have many causes but they may be divided into two large groups, viz. infectious and noninfectious. The infectious diseases may again be divided into two classes based upon their visibility under the ordinary light microscope. There are those for which a visible pathogen is present such as fungi, nematode, bacterial, or insect, and secondly those for which no visible cause has been demonstrated. Viruses, by the criterion of visibility are placed in the second category. From the aspect of visibility they resemble nutritional disorders but are readily separated from them by being transmissible and highly infectious.

It is this group, of infectious diseases caused by a nonvisible pathogen termed virus, that will be considered here. In Costa Rica, as in many other countries, the plant diseases caused by the fungi, bacteria, and nematodes are fairly well understood. Unfortunately, the di-

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seases caused by the nonvisible pathogens are not so easily studied nor as readily understood. In view of the need for advice concerning the nonvisible infectious pathogens the Costa Rica Government requested the assistance of a plant virologist. I was fortunate to visit Costa Rica for a period of two months in this capacity to work with personnel of the Plant Pathology and Entomology Departments of the Ministry of Agriculture.

The word virus when translated from the Latin would mean a "poison" or a "toxin." The word in modern times conveys to the average reader more than just a poison or toxin. It has become associated with small size, protein, and disease causing abilities. Definitions of viruses are almost as numerous as there are workers in the field.

The history of a plant disease now known to be caused by a virus may be traced back to about the middle of the 16th century. This refers to the variegation or color break in tulip flowers and is first seen in some of the paintings of the Dutch Masters. Virus diseases of potatoes can be traced back for hundreds of years and have caused degeneration or running out of many potato stocks. The history of "peach yellows" is almost as long as the degeneration of potatoes, for it was described as early as 1791. The first disease to be actually attributed to a virus is that of tobacco mosaic virus. Mayer in 1886 named tobacco mosaic but the distinction between viruses and other pathogens was not made until 1892. Iwanowski demonstrated the filterability of tobacco mosaic virus but he argued that the symptoms were caused by toxins or bacteria that entered the filter. Beijerinck fully realized the significance of filterability and called his preparation "*contagium vivum fludium*." For the next 30 years many infectious disorders were studied and described as virus diseases. In 1935 Dr. Wendell Stanley received the Nobel Prize for his work on the purification and crystallization of tobacco mosaic virus. F. C. Bawden in England in 1936, identified a similar product of tobacco mosaic virus as a liquid crystalline nucleoprotein containing nucleic acid of the ribose type and found the particles to be rod shaped. The discovery of the proteinous nature of the virus ushered in the modern or present day period of virus research.

With the ever increasing speed of travel and movement of plant materials between countries the necessity of increasing our knowledge of viruses and virus diseases becomes apparent. The close relationships between the U.S.A., especially the State of Florida, and Central and South America emphases the need for a mutual and common knowledge concerning the virus diseases of our similar plant material.

The techniques, procedures and equipment used in the study of plant viruses are entirely different from those used to study the fungi, bacteria or nematodes. From this aspect it seemed desirable to concentrate the two month period in Costa Rica on training the personnel involved with these procedures and techniques. By this means it was anticipated that the Costa Ricans themselves would be able to distinguish between the various virus diseases of plants.

In cooperation with Dr. R. H. Segall, Plant Pathologist, International Cooperation Administration, a green house was erected in

San Jose. Seeds of the plants used as differential hosts in the study of plant viruses were sent from Florida. Dr. Segall had them planted in San Jose and the plants were ready for use upon my arrival.

To facilitate the training of Ing. Morales, Entomologist and Ing. Rodriques, Plant Pathologist, in the techniques and procedures used in the study of plant viruses a series of lectures covering the various aspects of plant virology were prepared. The series included the following topics: Introduction, Symptomatology, Methods of Transmission, The Relationship between Viruses and their Vectors, Virus Strains, Serological Relationships of Plant Viruses, Virus Diseases and Host-Plant Physiology, Control Measures, and Speculation on the Origins of Viruses. Lectures and discussion periods were accompanied by field trips. Laboratory experiments were conducted in conjunction with each topic so that the personnel could actually see and practice the various techniques and procedures used for virus identification. The lecture and laboratory exercises were designed to cover the basic principles involved in plant virology. These principles would help enable the research worker to separate the diseases caused by viruses from the other infectious and noninfectious diseases of plants. They would also supply information on the identification of the virus involved, methods of dissemination alternate hosts, and methods of control.

Field trips were made to various parts of Costa Rica to survey the crops for virus diseases. The potato growing area of Irazu was surveyed and many of the potatoes exhibited symptoms which could be attributed to virus diseases. Samples were taken to the laboratory for identification and long term experiments were initiated on several of the diseases. The potato varieties grown in Costa Rica are different from the commercial potato varieties grown in the United States. These varieties exhibited symptoms different from those normally associated with the known virus diseases of potatoes. Thus, identification of the viruses in relation to the symptoms developed by the different varieties is needed. The bird-nest disease (huevera) of potatoes, so called because diseased plants produce many small, noncommercial sized tubers, needs identification as to its causal agent. Experiments were initiated to prove or disprove the viral nature of the bird nest and leaf roll diseases.

Coffee, one of the major agricultural crops frequently exhibit symptoms of "blister spot." This disease according to Dr. Wellman is caused by a virus. Experiments were started to prove the identity of the virus involved, its insect vectors, and the possible primary source of the virus..

Sweet yellow lupine (*Lupinus luteus*) widely used in the Southeastern United States as a forage and winter cover crop was on trial at the El Alto Experiment Station to test its potential in Costa Rica. A survey of the lupine plot revealed the presence of plants infected with bean yellow mosaic virus. This virus is responsible for a major disease of lupines in the United States. The virus greatly reduces the amount of seed set and is one of the major contributing factors to the reduction of acreage planted to sweet yellow lupine. The virus is transmitted through at least 6 percent of the seed formed on infected

plants. The virus has a wide host range in the family Leguminosae and is a potential disease to many leguminous crops. Whether the virus was introduced into Costa Rica in the lupine seed or already present in some of the native legumes was impossible to determine. The lupine crop was plowed under, to remove this potential source of the virus.

The bean, tomato, and pepper growing areas of Santa Ana and Alajuela were surveyed for the presence of viruses. Only a few bean plants were found infected with what appeared to be common bean mosaic virus and a few tomato and pepper plants were infected with tobacco mosaic virus. These crops, at least during the period of my visit, were very free from virus diseases.

The training of Costa Rican personnel in the field of plant virology was a worth while endeavor. This was due mainly to the receptive response on the part of the people with whom I worked and they could, if supplied with the necessary equipment and time, make a worthwhile contribution to the study of the virus diseases of plants in Costa Rica.

Experiences in Crop Production Research in Latin America

Joseph R. Orsenigo*

Certain qualifications are implicit to the experiences cited as illustrations of several types of research activity in which non-nationals participate in Latin American agriculture. The author is a North American with some five year's crop production research experience in two Latin American countries, Costa Rica and Venezuela. He has worked with sub-tropical and tropical agricultural crops, and, especially, with an agricultural specialty not yet mature—chemical methods of weed control. This paper combines a resume of research project activity with which the author was associated with some opinions on non-national participation in Latin American agricultural research.

The author's experience in Latin American agriculture began in 1948 during a one-year research fellowship in herbicides at the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica[1]. Graduate research with fungicides, herbicides and insecticides in tropical crops was conducted under a grant from the Standard Oil Development Company. Investigations with agricultural chemicals in tropical areas of Latin America was a forward-looking appraisal of the requirements for adapted pesticides.

Environmental conditions favorable for plant growth in tropical areas intensify the weed control problem. Annual rainfall may exceed 100 inches per year in low elevation areas while temperatures throughout the year are moderately high. Numerous weed species may flower and seed every month of the year in areas with short or poorly defined dry seasons.

Coffee, an important export crop and prime foreign exchange earner in many Latin American countries was the principal crop in the herbicide research program. *Coffea arabica* L., a perennial bush or tree crop, is grown under a fairly wide range of soil and climatic conditions. The coffee of commerce is produced as a fairly stable, long-term farm operation. Production units may be a family-sized five acres or plantations of hundreds of acres. Naturally, the type and size of farm varies within and among coffee producing countries. Plantations with full tree stand and uniform shade require less weeding. But, under most situations weed control is necessary in coffee plantations. The cultural methods generally used are ancient and require repeated, vigilant care; they are laborious and expensive. Machetting, shovelling, hoeing, or their local variations frequently result in incidental damage to the coffee bush. Incautious machetting slashes the lower trunk and the wound may be an entry of subsequent

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[1]In a program directed by Dr. Ora Smith, Cornell University; Herbicide fellows from 1947 to 1949 were Milton E. Gertsch, Jose I. Nunez G., and Joseph R. Orsenigo.

pathogens while shovelling generally severs and exposes some of the superficial feeding roots. The long-time effect of exposing coffee soils to direct sun and rainfall have not been critically evaluated nor has the role of weed cover in retarding erosion on sloping lands been determined.

The herbicide requirements of the program were two fold: control of emerged weeds and prevention or retardation of further weed emergence. An herbicidal treatment which would combine both in one application would be most desirable. The treatments would have to be inocuous to the coffee tree and resist both climatic weathering and the soil disturbance which ordinarily accompanies cultural operations by laborers in the plantations, viz., fertilization, pesticide application, pruning, and harvesting.

Hundreds of herbicidal treatments were evaluated from 1947 to 1949. The most promising chemicals and combinations were selected and re-appraised on a larger plot scale for continued weed control effectiveness and apparent effect on the coffee tree. Yield data were not taken in early evaluations.

The most effective herbicidal treatments included the following chemicals alone or in combination: DNAP and DNBP, dinitro-o-sec amyl and butyl phenols; PCP, pentachlorophenol and its sodium salt; TCA, sodium trichloroacetate; 2,4-D, esters of 2,4-dichlorophenoxyacetic acid; and aromatic or herbicidal oils (1)[2]. Both contact and residual weed control were enhanced markedly by applying the chemicals in oil or in oil-water emulsion carriers. Treatments applied at 30 days after shovelling usually afforded better weed control than those applied at 10 days after shovelling. The dry season of the year appeared most advantageous for establishment of a chemical weed control program in coffee. Superior treatments obtained progressively longer periods of weed control per application through successive sprays. Repeat applications of a "spot" nature (i.e., partial area spraying only where weeds were present) to maintain control helped reduce chemical and application costs to levels competitive with manual culture which then cost \$9.00 to \$16.00 per acre per year. Two applications of several of the superior treatments maintained commercially adequate weed control for one year under good coffee tree stand and fairly dense shade cover.

Systemic foliage distortions in coffee were observed when 2,4-D was applied to the soil surface under the trees as well as to the foliage (2, 3). The distortions were not apparent in new tree growth several months after 2,4-D application but reappeared anew after each use of this herbicide. Yield and associated effects were not investigated completely. Treated trees seemed to bear as well as control trees and seed harvested from trees with distorted foliage germinated and grew normally in the seedling stage (4). In many 2,4-D-treatment plots the only vegetation was volunteer coffee seedlings.

Superior herbicidal treatments were established in "off station" demonstrations in commercial plantings in several producing areas; two typical treatments are listed in Table 1. Herbicides, reasonably

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[2]Numbers in parentheses refer to references cited.

effective under diverse demonstration conditions, were not readily adopted by growers for trial use on their farms.

Currently, the superior treatments in Table 1, or close variations of them, are used commercially and semi-commercially in coffee plantations in many coffee areas, especially in Costa Rica. Recently it has been estimated that 10,000 or more acres of coffee are treated annually with herbicides (5,6). The following materials are used most commonly: oils, DNAP and DNBP, PCP, 2,4-D, TCA, and dalapon.

TABLE 1.—Two Superior Herbicidal Treatments Developed for Trial Use in Coffee at the InterAmerican Institute of Agricultural Sciences, Turrialba, Costa Rica, 1947-1949.

Components	Rate Per Acre
1. PCP (or its sodium salt)	4 lb.
2,4-D, butyl ester	1 lb.
Aromatic oil	10 gal.
Emulsifier	1 lb.
Water	90 gal.
2. DNAP	1.5 lb.
2,4-D, butyl ester	1 lb.
Aromatic oil	10 gal.
Water	90 gal.

N.B. Rates are in terms of acid equivalent or active ingredient, whichever applies to the particular component. Diesel oil was recommended as a substitute for the heavy aromatic naphthas or similar petroleum products at twice the aromatic oil rate. Both treatments may be made up to 50 or 100 gallons per acre by adjusting water, oil, and emulsifier quantities as required.

Why was there a delay in grower trial evaluation, acceptance and adoption? Perhaps, the research program was too short-lived for full treatment development or the provisional findings were disseminated inadequately. It is plausible, however, that the research pre-dated an economic need for this new aid in coffee production. Herbicides were a new tool and concept, not fully investigated, and unfamiliar to most potential users. Also, on many large plantations weeding chores help equalize labor distribution between peak periods of activity. The recent rising costs of labor and supplies have induced growers to seek economies at all stages of coffee production and the newer techniques are more appealing now.

Weed control research with sugar cane at the Institute was conducted on a limited scale. The evaluation experiments developed several apparently effective treatments similar to those listed for coffee and to others used commercially in Puerto Rico, Cuba, and Hawaii. More than two months of weed control were attained, but the treatments were poorly adapted to the cultural practices then followed.

Research in chemical weed control for field corn led to treatments which would maintain commercially adequate control of grass and broadleaf weeds for 90 days or longer without mechanical cultivation. (Figure 1). Yields were satisfactory under good plant populations. The most effective treatments utilized DNAP and DNBP, PCUP 2,4-D

Figure 1.—Right, effective weed control with 2,4-D, butyl ester at 2 lb/A applied in 16 gpa of aromatic oil; left, untreated control. Photographed at 90 days after pre-emergence application of the herbicide in a demonstration at the InterAmerican Institute of Agricultural Sciences, 1949.

and oils and were similar to those formerly and currently recommended by several of our state experiment stations. Neither corn herbicides nor trial treatments developed for dry beans have had much utilization.

The author acquired additional crop production research experience in Latin America in 1953-1955 with the IBEC Research Insti-

tute (IRI) in Venezuela. This private research group originated short-term programs to study methods of improving production of corn and rice, two basic foods in Venezuela. Deficit production of these crops in many years had to be met by large imports to fill national consumption needs. The major portion of the rice crop came from mechanized operations; private farms, farms in the government's "Programa Arrocera," and certain colonization projects. The production of small-scale and subsistence growers had little influence on commercial channels. National rice yields were low: rice culture was principally "upland" or non-irrigated with low seeding and fertilization rates and wide-spaced rows to permit mechanical cultivation.

A major influence in limiting efficient large-scale rice production under upland conditions was the inability to control weed infestations adequately. Weeds contributed directly to high production costs and low yields. Successive rice crops on the same lands were conducive to weed and grass infestations which frequently led to abandonment after three or four year's cropping. Under normal practice rice was drilled in wide-spaced rows to permit tractor or manual cultivation for the control of weeds. Untimely or prolonged rains precluded effective tractor operations and lead to costly and partially effective hand methods.

The IRI rice program in the Estado Portuguesa rice area was characterized by the following aims:

a.) develop effective pre-emergence herbicide treatments to control weeds; b.) determine desirable planting density with close row spacing or broadcasting; c.) determine optimum seeding rate for the several seeding methods; d.) determine optimum fertilization for the planting systems in (b) and (c); e.) develop good management practices combining weed control chemicals, rate and method of seeding, and fertilization; and f.) investigate the potential of irrigated rice production.

Over a period of several years some of the indicated goals were attained on an experimental small-plot basis (7, 8, 9). Unfortunately the program was terminated before repeated annual trials could provide more complete agronomic assessment of these production factors.

Effective herbicidal treatments were developed for two soils common to the area (Table 2 and Table 3). Upland rice yields two to four times the national average were obtained on a small plot basis with several herbicides. Particularly effective were CIPC, DNBP, PCP, and diuron (Figure 2). The costs of these treatments were competitive with accepted average manual and mechanical expense.

Subsequently, three of the foregoing herbicides were used commercially in rice production in Venezuela. Both ground and aerial applications were made to several thousands of acres under a wide range of conditions prior to termination of the IRI program. The promise of herbicides as a tool in upland rice production in Venezuela has been substantiated by continued commercial acceptance and use.

Yield increases gained experimentally through close row spacing are illustrated by data obtained in upland rice planted at two spacings under three rates of application of each of two herbicides (Table 4).

TABLE 2.—Average Values for Rice Stand Reduction, Days of Adequate Grass Weed Control, and Yield of Rough Rice for Selected Pre-Emergence Herbicidal Treatments on Black Llanos Soil at Acarigua, Venezuela, 1954.

Herbicide and Rate, lb/A.		Mean rice stand reduction	Mean days adequate grass weed control	Relative mean yields rough rice
Hand weeded,	21 in. rows*	—	123 days	3300 lb/A
CIPC	5.3 lbA	4%	<16	4130
	8.0	11	123	4170
diuron	0.7	17	<72	4190
DNBP	4.4	4	123	4490
	6.2	34	123	4140
PCP	22.3	18	123	4400

*Local practice; herbicide plots were drilled at 7. in.

TABLE 3.—Average Values for Rice Stand Reduction, Days of Adequate Grass Weed Control, and Yield of Rough Rice for Selected Pre-Emergence Herbicidal Treatments on Red Llanos Soil at Acarigua, Venezuela, 1954.

Herbicide and Rate, lb/A		Mean rice stand reduction	Mean days adequate grass Weed control	Relative mean yields rough rice
Hand weeded*		--	120 days	3600 lb/A
CIPC	5.3 lb/A	20%	<19	2280
	8.0	34	<75	3370
diuron	0.7	32	<19	2540
DNBP	4.4	34	<19	2160
	6.2	40	<19	1930

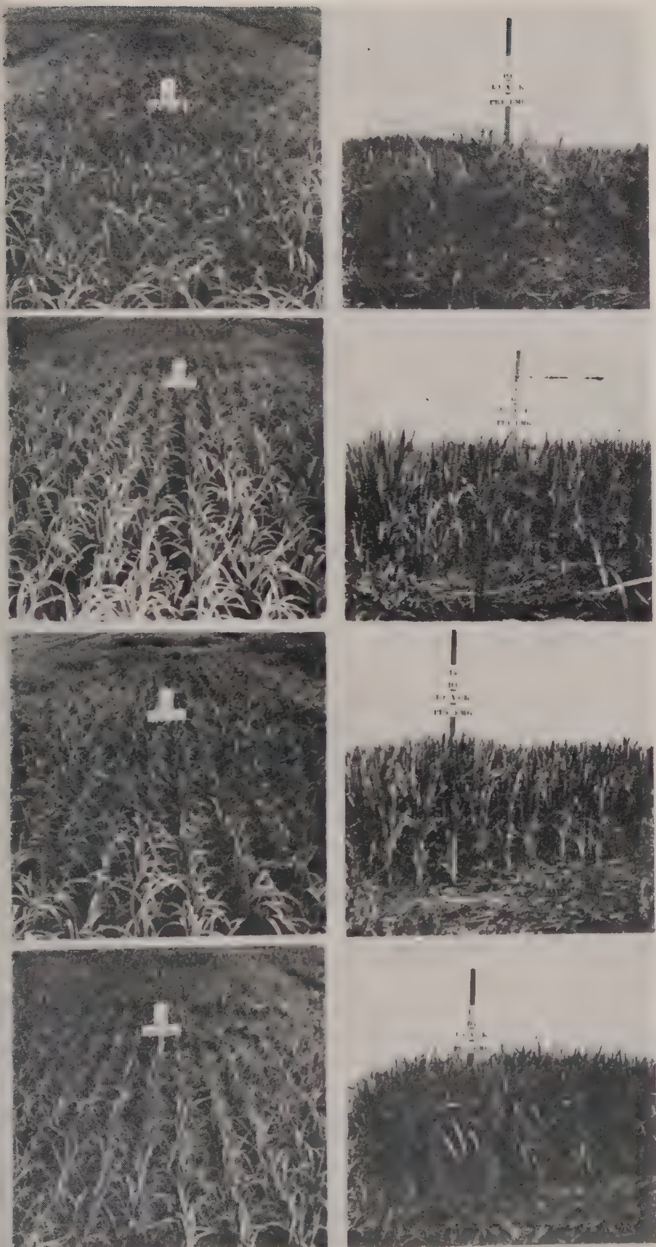
*All plots were drilled in 7 in. rows. Hand weeded plots kept completely weed-free.

TABLE 4.—Relative Mean Yields of Rough Rice Produced Under Three Rates of Two Herbicides Applied Prior to Emergence of Upland Rice Drilled at Two Row Spacings on Black Llanos Soil at Acarigua, Venezuela, 1953.

Herbicide and Rate, lb/A		Relative mean yield, lb/A. 7 inch	21 inch	Yield increase, 7 in. spacing over 21 inch
DNBP	2.7	2300	1940	360 lb/A
	4.0	2990	2610	380
	5.3	3190	2590	600
PCP	4.4	2130	1390	740
	8.9	2240	2100	140
	13.3	2640	2370	270

The average yield advantage for close spacing was about 400/lb when the same seeding rate was used for both spacings. More rapid shading of the inter-row area at the close row spacing helped to maintain more complete weed control.

Rate and method of seeding upland rice on the same soil were evaluated the following crop year under a uniform herbicide treatment. Yields of rough rice in combine harvested plots did not differ significantly (Table 5). But, it is interesting to note that equivalent



Untreated control plot, 970 lb. rough rice/A

diuron, 0.9 lb/A. 3740 lb. rough rice/A.

CIPC, 8 lb/A. 4170 lb. rough rice/A.

DNBP, 4.4 lb/A. 4490 lb. rough rice/A.

Figure 2.—Paired photographs of pre-emergence applied herbicidal treatments in upland rice on black llanos soil at Acarigua, Venezuela, 1954. Left column photographed at 25 days after planting; right column at 69 days after planting. Herbicidal treatment and relative mean yield at right of each pair of photographs.

TABLE 5.—RELATIVE MEAN YIELDS OF ROUGH RICE FOR TWO RATES OF DRILL AND BROADCAST SEEDING OF UPLAND RICE ON BLACK LLANOS SOIL AT ACARIGUA, VENEZUELA, 1954.

Seeding Method and Rate, lb/A		Relative mean yield
Broadcast	111	3170 lb/A
	142	3240
Drill, 7 in	80	3070
	111	3250

yields were obtained from broadcast seeding at 142 lb/A and 7 in. drill seeding at 111 lb/A.

Rice fertilization experiments with upland rice on the black llanos soil in two years did not lead to clear-cut, conclusive values. The data did permit a provisional estimate of range for adequate nitrogen fertilization.

A highly significant straight line yield response to nitrogen fertilization was obtained with upland rice on the red llanos soil in 1954 (Figure 3). However, the increased yields with nitrogen fertilization were accompanied by highly significantly increased panicle "rotten-neck" (Collar infestation of *Piricularia* sp.). Despite a very noticeable stimulation of plant vigor, phosphorus fertilization did not influence yield. Potassium fertilization did not affect yield significantly but reduced panicle "rotten-neck" when applied at 53.4 lb/A.

Regardless of seeding rate yields of irrigated rice were significantly higher under broadcast seeding. Yields did not differ significantly among the three seeding rates common to drill and broadcast methods (Figure 4).

Several other irrigated rice experiments were conducted. One evaluated several water control operations: the principal function of flooding rice is weed control. Excellent grass control was obtained by about 40 days of flooding. Similar control was achieved by 10 days flooding when DNBP had been applied as a pre-emergence herbicide. Differences in yield among three flooded treatments were not significant and their yields were not related to the average amount of irrigation maintained on the experimental paddies (Table 6).

The IRI rice program, although of short duration, provided information of value in an important rice area of Venezuela by concentrating on several production factors not studied previously. Data applying to rate and method of seeding, and fertilization were obtained for two "upland" situations. The great potential of irrigated rice production in this area was demonstrated. The pre-emergence herbicide program was successful in developing effective economical treatments which permitted improved agronomic techniques on two soils. The most promising herbicidal treatments have continued as commercial.

A similar program was carried forth by IRI with field corn in several areas of Venezuela (10, 11, 12). These investigations included pre- and post emergence herbicides and period of weed control as well as plant population, spacing and fertilization. With herbicides on

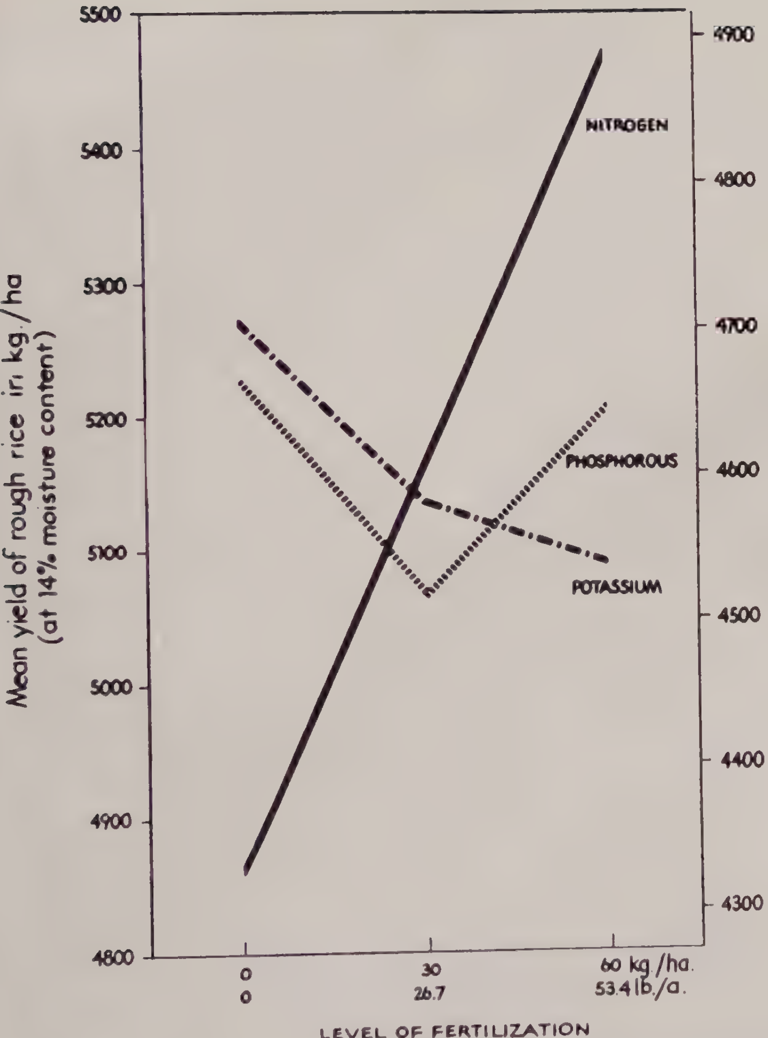


Figure 3.—Mean yields of rough rice produced under three levels each of nitrogen, phosphorus and potassium fertilization under upland conditions on red llanos soil at Acarigua, Venezuela, 1954. Rates are in terms of N, P_2O_5 and K_2O for the respective fertilizer materials.

some soils it was possible to grow corn to maturity without cultivation; experimental yields of 80 to 100 bu A were attained under good management practices.

The author's third and most recent experience in Latin American crop production research combined administrative, research and occasional teaching and training duties at the InterAmerican Institute of Agricultural Sciences. This agronomist-horticulturist position in

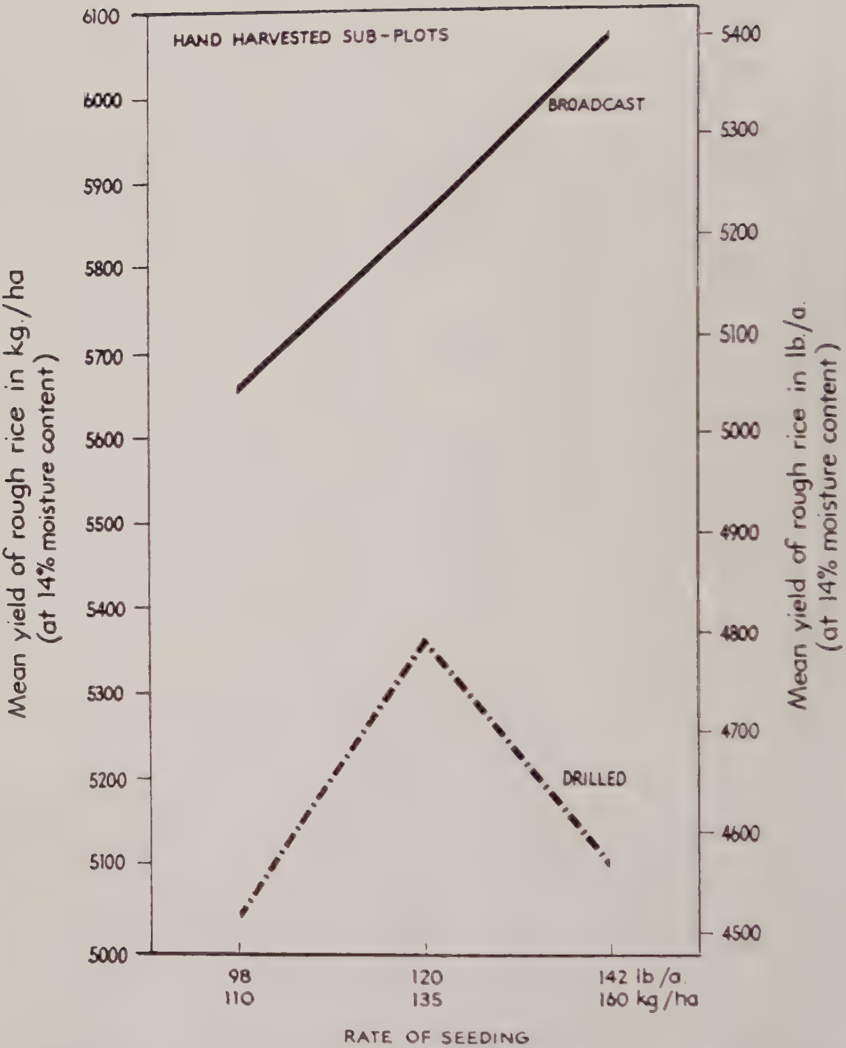


Figure 4.—Mean yields of rough rice produced under three levels each of drill and broadcast seeding in irrigated paddies on black llanos soil at Acarigua, Venezuela, 1954. Drill seeding was at 7 in. row spacing.

the InterAmerican Cacao Center covered the period from mid-1955 until early-1957. Some research with cacao, *Theobroma cacao* L., a perennial tree crop, was conducted at the Institute's tropical lowland experimental farm.

A soil survey project was prepared and accompanied by an estimated soil use reconnaissance of 220 acres of this 40-year old cacao plantation. Approximately 15 percent was in experimental use and was adapted to future experiments. An additional 30 percent of the farm was judged suitable for then current and future experiments

TABLE 6.—RELATIVE MEAN YIELDS, YIELD DIFFERENCES AND THEIR VALUES AMONG THREE IRRIGATION TREATMENTS ON BLACK LIANOS SOIL AT ACARIGUA, VENEZUELA, 1954.

Irrigation treatment	Relative mean Yield, lb/A	Increases over treatment 1	
		Mean yield lb/A	Value $/A
1. Continuous flooding until heading	3880		
2. Continuous flooding until harvest	4130	250	21.00
3. Pre-emergence DNBP + treatment 2	4220	340	28.00

N. B. Yields did not differ significantly.

while the balance was classed not suitable for experimental use but adapted to continued commercial production. A detailed plantation condition survey was made on some 50 acres of the farm to evaluate a restricted area for experiments with old bearing trees. Only 68 percent of the trees present were normal or average producers. Of 668 trees sites per hectare the area surveyed only 268 trees per hectare of comparable growth and condition adapted for experimental use. Yet, the production of this area was approximately double the national average. During this survey it was apparent that replanting of vacant tree sites or replacement of incompatible or low producing trees with young material was inefficient, costly and wasteful of plant material. Few replants survived to maturity in the aged experimental plantation. Annual small block replacement of old cacao seemed to be the most effective management.

Prolonged excessive rainfall appears to have a pronounced effect on tree physiology, slowing growth and fruit maturation, as well as favoring scope and intensity of disease infections. Data for rainfall and farm production for a six-year period were analyzed statistically; there was no gross correlation between monthly rainfall and production one, two, three, four or five months later.

Weed growth is rarely a problem in well-established mature plantations since ground shade is heavy. In young cacao fields and at missing tree sites vigorous weed growth necessitates repeated manual control. Small demonstration herbicide plots were installed in lightly shaded areas of young cacao. One treatment, DNBP + dalapon + 2,4-D, provided two months excellent control of grass and broadleaf weeds with one application and four-month control seemed probable.

Many old and poorly managed cacao plantations are marked by excessive numbers of undesirable shade tree species. Some species continue to live for three to four years after incisive girdling. Screening experiments with silvicides for rapid selective thinning of undesirable cacao shade trees were begun. Arsenicals impregnated on blotting paper and inserted under the bark were most effective with several species.

Both research and residence experience were acquired together and were difficult to separate. Recurrent events have led to the opinions below on agricultural research in Latin America and non-national participation.

Generally, agricultural research in Latin America is not as extensive or as intensive as would be desirable even in countries which derive 90 percent of export income from agricultural products or in countries which must import basic foods to offset the deficit between national production and consumption. Small-scale or subsistence farming cannot feed many persons while large-scale farming may compare poorly with other investment possibilities. The latter situation is more apt to food crops for national use rather than export crops. If farming is not vigorous and profitable then agricultural research may be less attractive. Youth can be drawn to or trained in more appealing and remunerative occupations. Agricultural research at national, international and private levels suffers, in general, from the lack of long-term funds and freedom to develop a constant research program adapted to local needs. Poorly implemented programs may inhibit future support.

The North American, or other non-national, who resides and works in Latin America is a "foreigner." This is self-evident daily in many ways, but especially, in language and in understanding and appreciation of national customs, traditions and philosophies. These personal aspects have their professional counterparts. To be effective the researcher must become more than superficially "acquainted" with local and regional agriculture. He must become knowledgable at first hand and in depth with agricultural development and problems. This requires time. Several research organizations in Latin America estimate that a researcher does not become professionally productive on his first tour of duty until he has lived and worked in his host country for about two years. If a researcher is to work with a previously unfamiliar crop he must study that crop and its literature. Good bibliographic facilities, although important, are scarce, and the literature, if available, may be in an unfamiliar language. These handicaps should force the researcher to utilize his knowledge of principles in research rather than rely upon familiar temperate climate specifics. The impulse to remedy a situation by applying midwestern mechanized corn production techniques needs restraint. Many of the world's food and export crops are grown on lands and scales not amenable to motorized equipment.

A person with temperate climate experience responds instantly to hillside cultures, especially when crop rows are up-and-down slope. But, even under high rainfall on certain soils experience and experimental data demonstrate that hillside cropping on 45 percent slopes may cause negligible erosion (13). This can be true of soils of recent volcanic origin and more developed soils with specific clay and aggregation properties. On other soils, under similar climate at the same latitude, yearly erosion can be measured in tons per acre.

Geo-ecology and the reasons underlying regional practices should not be neglected. On the edge of the great Venezuelan llanos small-scale, subsistence farmers successfully grow their small "conucos" of corn under a system of shifting cultivation. Forest trees are felled to make small clearings which are farmed for two or three years before abandonment to weeds, brush and trees. An attempt was made to extrapolate this success to large-scale production of corn with de-forest-

ing and application of North American corn culture techniques. The results were very disappointing when both weed infestations and the high rainfall of the cropping season exerted their effects. Fields were spotty in corn growth and development and yields were poor: the experiment was a failure. The subsistence farmer had not been observed closely. He chose an ecological forest site and cleared certain species associated with slightly higher and better drained soils which would support corn. He cropped his patch until weed control became too laborious; then, he moved on to another patch before the ability of the first to support vegetation was exhausted by tillage, crops, oxidation and leaching. Many have been impressed by the verdant vegetation of the tropics and sub-tropics and envision great production of food crops in the future. A partial answer to these proposals has been provided in brief form (14). From experience now available it is certain that in many areas of the world "shifting cultivation" must be the rule.

Indigenous food crops have been neglected in crop production research in most countries. Long accustomed local foods; cassava, *Manihot utilissima; Alocasia; Colocasia; Dioscorea, Ipomoea,* and others are amenable to improvements which would benefit national consuming populations. The need for more concentrated cattle feeds for production of animal and animal products exists in practically all tropical lands. The place of cacao pod meal, mechanical dewatering of forages and other techniques needs more vigorous investigation as to practicality and economics.

Research and development must rest upon an adapted, long-term, well-financed program adequately staffed by competent persons. The tour of duty of non-nationals should be sufficiently long to permit professional productivity. The base of the program should be a long-term fundamental approach to provide sound crop and production improvement but short-term projects should not be neglected. Consultants have an important role in implementing research but the field program should be executed by staff in residence. In outlining a program, serious consideration must be given to the production potential and economic possibilities of the crop and its importance in export or in home consumption. An example may be taken from cacao. Control of plant diseases is an outstanding problem; but, there are several deterrents to fungicidal treatments even when recommendable. In some producing areas many plantations are small or topographically difficult to spray effectively; and, augmented yields may not cover the cost of spraying. Another kind of problem in some regions may be the lack of price differential between bulk-run, indifferently processed cacao with that which is highly acceptable commercial product. There must be an incentive to utilize improved crop technology.

REFERENCES CITED

1. Smith, Ora, Joseph R. Orsenigo, and Milton E. Gertsch. 1950. Chemical weed control in coffee. Proc. Northeastern Weed Con. Conf. 4:105-110. (see also: Turrialba. 1:280-283. 1951; LaHacienda 48 (3):44-46, 68. 1953; or O'Fazenda. 48 (6):47-49, 56. 1953.)

2. Havis, John R. 1952. Danos en cafetos causados por herbicidas. Turrialba. 2:170-171.

3. Orsenigo, J. R., R. H. Segall, Ora Smith, and F. L. Wellman. 1953. Systemic foliage distortions in coffee attributed to 2,4-D. Turrialba. 3:100-101.

4. Orsenigo, Joseph R. 1949. Unpublished data. Project 55. Inter-American Institute of Agricultural Sciences.

5. Anonymous. 1957. Control quimco de malezas en cafetales. Informacion Cafetalera No. 4. Alberto Franco B., Editor. Instituto Interamericano de Ciencias Agricolas.

6. Perez, V. M. 1958. *IN* Abonamiento, poda y combate de mala hierbas en el cafeto. Suelo Tico. 10 (39):79-88.

7. Efferson, J. N., et al. 1953. Report on Venezuelan rice experimental program for 1953. IBEC Research Institute Bul. 3. p. 38.

8. Orsenigo, Joseph R. 1955. Preliminary technical report 1954 Venezuelan rice program. IBEC Research Institute. Mimeo p. 430.

9. Orsenigo, J. R. 1956. Rice investigations in Venezuela in 1954. IBEC Research Institute Bul. 8. p. 28.

10. Young, E. F., Jr. and B. A. Krantz. 1954. Report on Venezuelan corn experimental program for 1953. IBEC Research Institute Bul. 5. Mimeo. p. 36.

11. ---- ---------- and J. R. Orsenigo. 1955. Preliminary technical report 1954 Venezuelan corn experiments. IBEC Research Institute Mimeo. p. 198.

12. ---------- ---- and ------------ . 1955. Corn investigations in Venezuela in 1953 and 1954. IBEC Research Institute Bul. 7. p. 19.

13. Ives, Norton C. 1951. Soil and water run-off studies in a tropical region. Turrialba. 1:240-244.

14. Pendleton, Robert L. 1952. The tropics . . . will they feed tomorrow's millions? Crops and Soils. 4 (4):16-19.

Education and Training for Agronomic Development in Latin America

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"This is Big Bear coming downstairs now, bump-bump-bump on the back of his head, behind Christopher Robin. It is, as far as he knows, the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment and think of it. And then he feels that perhaps there isn't. Anyhow, here he is at the bottom and ready to be introduced to you." Thus A. A. Milne presents the world famous character Winnie-The-Pooh. And that is all I am going to do tonight—to attempt to stop and think for a few moments about education and training in relation to agricultural development in Latin America. Much of it may be purely more of the old head-bumping which has grown up about the various activities which are planned by societies to fit their citizens for life. But the subject is one which merits better treatment. Development is a human process which depends on men having knowledge and acquiring the art of using knowledge. This is the inescapable mandate of whatever civilization we are to have.

There probably have been times when complacency was in order. Perhaps one of those times was that of the Pax Romana during the first two centuries of the Christian era. Roman discipline and Greek culture blanketed so much of the known world that either through subjugation or loyalty the affairs of men ran smoothly. But today we are closer to the dark ages when barbarians were at the frontiers and internal security was a matter of continual vigilance. The organizing effect of empires is disappearing (at least in the free world). The substitution of unilateral means of maintaining relations by international organization is in its infancy. The pressure of population on resources is increasing rapidly. At the same time increased media of communication are causing expectations of a better life to rise faster than the applications of means for improving living conditions. We see freedom of individuals continually threatened at arbitrary government attempts to take advantage of the resulting chaos. Widespread demands for raising levels of consumption without employing the requi-

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site technology have always brought about exploitation of natural resources and social instability.

Ways must be found to match the ferment for change with the requisites for constructive development. No amount of imported "know-how" will solve this problem. Changes, if they are to be productive, must be locally managed and locally inspired. It takes breadth of vision, understanding of situations, convictions—and the appearance of the right man at the right time. This means preparation of a significant proportion of the available talent, effective research into all pertinent factors and effective public services. Furthermore, it will require an even greater recognition in our hemisphere that we can rise or fall together. In this respect the State of Florida has a great opportunity and a consequent responsibility. The accident of geography which has thrust this peninsula out into the tropics near in distance and in ecological conditions makes it a natural training ground for the developers of our neighboring countries. The results of its graduates and its emmissaries are already noteworthy. We hope they will be multiplied. We need more men like the late Harold Mowry. It is not necessarily the Humboldt's who transfer most successfully the organizing skill from one area to another. We need the quiet, steadfast men like Mowry who through the greatness of their character build a school of young men around them and radiate influence.

As we face the problem of education and training for agronomic development certain situations seem to be of particular importance in Latin America. First off it is underdeveloped in the sense that great opportunities exist for increasing production. Relatively extensive areas of virgin forest still exist. Probably one quarter of all the forests remaining in the world are in Brazil alone. Fifty percent of Costa Rica is in largely undisturbed timber. In the past, labor has been wasted in most of the cultivated areas to save all other expenditures. Only recently has it become necessary to apply technology and the products of industry to save labor and increase yields. Even so, food production has not increased as fast as population during the past decade, and it takes as many man-hours to produce a quintal of coffee as it did 100 years ago. Another situation is that much of the area lies within the tropics. This has meant that the crop and animal varieties and the cultural practices which came from the old world to the new were unadapted to, at least, the lowlands. The time factor has also been of importance. North America experienced the exhiliarating effect of independence from the old world some fifty years before Latin America. These were strategic years. While the north was getting ready to make the most of the industrial and the agricultural revolutions, Latin America was fighting to remove the dead hand of the past. Out of the complex of circumstances it also developed that much of Latin America became saddled with a system of blighting, centralized authority which persists in many countries to this day. Probably no society can make optimum progress when it is denied the initiative and the specialized knowledge which exist in rural communities. The success of a democratic system depends on the individual, the family, the community, the most local governing unit

handling all of their affairs that cannot be handled for technical or other reasons to a better advantage by more centralized authority. In general people cannot be taxed sufficiently to meet the needs for schools and roads unless they levy a portion of their own taxes and spend the proceeds themselves. Also, so long as essential decisions governing the welfare of rural people have to be made in capital cities, many of those decisions will be badly made.

Out of these situations (and contributing to them) grows the fact that some 50% of children of primary school ages are without schools, only 7% of those of high school age are in school. The percentages in higher education are less. Of those in school most are city residents. Coming more directly to our problem, Latin America has about 16,000 technical workers in agriculture. About 40% of these are in commercial activities some of which are unrelated to farming. The remainder are mainly in government service and in public institutions. Based on a survey of agricultural education carried out by the Inter-American Institute of Agricultural Sciences and FAO[1], the Latin American Deans of Colleges of Agriculture assembled in Santiago, Chile last March estimated that 26,000 additional technicians are needed[2]. These would be needed if all the research, educational, extension, rural development, and administrative units of the twenty countries were adequately manned. Of these 16,000 existing technicians, it was estimated that 153 have the M.S. degree and 29 were Ph.D.'s in 1957[3]. The Deans calculate that the 44 Agricultural and Veterinary Colleges enroll about 6,800. They could enroll about 12,000 if these problems were solved:

1. Job opportunities have increased rapidly in agriculture but this fact is not well known. Technical agriculture is still considered by many to be a poor relation of the learned professions.
2. Many prospective students lack funds for travel and maintenance.
3. Some institutions lack certain physical facilities.

Even if these problems were solved, say the Deans, it would take 30 years to fill the demand. It should also be remembered that whereas there is one farmer producing for 22 others in the United States, on the average the Latin American farmer produces for less than six. The range is from one farmer for 11.8 to one for 2.2. The lower ratios are of course in the tropics where more problems are unsolved and the public institutions for solving problems are least prevalent. The difference between 22 and 6 in the above is the difference between the ability to develop a balanced economy with high levels of both material and cultural consumption and a hand to mouth subsistence situation with an attendent inability to become a functioning part of the modern world.

Placing these facts in the context of our present discussion, it be-

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[1]Alvaro Chaparro, "Un Estudio de la Educacion Agrícola Universitaria en América Latina." Roma, December 1957.

[2]"Primera Conferencia Latinoamericana sobre Educacion Agrícola Superior." Roma, 1958.

[3]Alvaro Chaparro, Op. Cit. p.209.

comes evident that trained man power is scarce in agriculture and will remain so for years to come. A pertinent question then becomes, "how can we minimize the crippling effect of this scarcity on our agronomic development?". There is no pat answer to this question but some things are being or can be done. These circulate around improvements in quality of education and selection of talent, more effective use of exchanges and cooperation within Latin America and with other areas (mainly the U.S.), improved communications, and the general development of more of a common concern for the entire problem of scientific and technical man power scarcity. These will be discussed during the remaining pages of this paper.

There is a rising ferment of change in Latin America. This is perhaps reflected best in the expressions of the Agricultural Deans during the meeting mentioned above. Aside from realistic estimates as to the quantitative aspects of the problem already cited they attempted to see more clearly their role in the societies they serve. Here is a summary of their Aims and Principles of Agricultural Education expressed in terms of the opportunities and responsibilities of the Agricultural College:

1. As an integral part of the university it should awaken and stimulate scientific spirit, method, and ambition.
2. Take as its principle objective the preparation of professionals of basic scientific competence led in the direction of acting effectively as researchers, extensionists and educators, as enterprizers and administrators of the natural resources of the nation who participate actively in economic development and in the application of science and technology to agriculture.
3. Remain flexible and responsive to the need for efficient training in any of the fields or at any level required for national agrarian development.
4. Methods of teaching, the attitudes and atmosphere of the university must aid in developing the ability of the student both to think and to apply knowledge to the solution of new problems.
5. It should offer a balanced program in the physical, biological, economic and social sciences and the application of these to the development of agriculture and rural life—not to forget that along with soils and plants there exists man and the community.
6. Serve as an open door for the entrance into higher education for those rural youth who have the necessary capacity but now lack the necessary opportunities to continue with their studies.
7. To promote the development of stable rural institutions and the ethics and professional prestige required in achieving common objectives.

The Deans want more fellowships for foreign study of staff members and graduates. They also want fellowships more directly applicable to their specific problems and less involved in formalities. They want more visiting professors. They say that visiting professors in the past have been most useful:

1. When they know the language and have had some familiarity with local customs and agriculture.
2. When their main function was to advise a local professor.
3. When the duration of service was long enough to make a permanent imprint, yet not so long as to inhibit the formation of local professors.
4. When the contribution of the visiting professor was complemented with foreign study fellowships aimed at improving the understanding of his collaborators.

Recognizing the need to make optimum use of foreign (non Latin American) training the Deans also see that their own resources for producing specialists must be utilized and improved. In response to their request and because of other indications the Inter-American Institute of Agricultural Sciences is now exploring the possibilities for establishing a cooperative system of graduate studies and regional research. This project will be under the general coordination of the Institute and will, it is expected, receive aid from FAO, Point Four and others. The Rockefeller Foundation has supplied a grant for preliminary assessment of available facilities. Ten years of experience by the Turrialba Graduate School has demonstrated that we need a combination of foreign training for the highly specialized and opportunity for medium specialization within the cultural and physiographic environment of Latin America. Valuable also to the present effort is seven years of offering up-grading short courses at Turrialba and through the Technical Cooperation Program of the Organization of American States in various other centers. The 5,000 technicians who have passed through these courses constitute a valid cross-section of our technical man-power. They are also a widespread and effective constituency in promoting cooperation.

Now let me see if I can bring this developing system of cooperative education and research home to Florida. At the present the scheme in its entirety is being applied only to the Temperate Zone of South America. However, throughout the Tropical Zone a service of cooperative research programs on corn, dairy cattle, potatoes, etc. has been developing for some years. The principle of common use of peculiarily adapted national programs is applicable to all areas. Why should we not include the remarkable combination of natural conditions and institutional facilities of this subtropical gulf area in a formal network of services embracing the Caribbean? To an extent the rudiments of such participation already exists in the cooperation between Florida and Costa Rica, in the membership of Latin Americans in the Florida Soil and Crop Science Society, in the Conferences on the Caribbean.

Communications also help to extend scarce technical resources. H. G. Wells said in his book, America: The New World, that all changes in civilization are referable to changes in processes of communication. A reference was made previously to the effect of widespread knowledge of advances toward the good life on the expectation of peoples everywhere. It is also apparent that useful ideas are the monopoly of no restricted group of people. They occur everywhere that men have an opportunity to understand, and the society that

has and utilizes most of them tends to progress the fastest. The Scientific Communications Service of the Inter-American Institute of Agricultural Sciences has been at the task of keeping our colleagues of the Americas informed for the past ten years. It publishes journals on research and extension. It sends out some 40,000 photocopies of scientific articles each year. Its Research Communications Service receives progress reports from 2,200 technicians and broadcasts these throughout the hemisphere.

The Deans in the report cited recommend that a service for the production and distribution of teaching materials be organized. They want this to include improvements in the availability and use of audio-visual aids, texts, and reference materials within Latin America and between them and other areas of the world. Such materials as texts on crop production from the subtropical area of the U.S. could be used to a much greater extent either directly or with minor adaptation and translation. In the basic sciences still greater possibilities exist. Mathematics and the physical sciences apparently are not conditioned by environment. The extensive program of revising basic texts now going on in the United States should supply materials in these fields for all the Americas. A means should be found for the necessary translations.

In the emergent countries, those concerned with agricultural education face grave responsibilities. It is evident that theirs is the task of leading the way toward development. Until the present agricultural sources of wealth are made efficient all other development is curtailed. Fortunately this situation is becoming recognized among institutions if not always among governments. The fact is evident in two general conclusions which can be deduced from the Survey of Agricultural Education in Latin America:

> *First*, the process of developing teaching programs rather than following the accretion method of adding on new subjects is beginning to involve study of needs and of the essentials of education. An example is the tendency to realize that the farm, the home, and community should increasingly guide efforts to strengthen programs.
>
> *Second*, although there is a ferment of change impending in agricultural education most programs are not going to be modified purely because change is fashionable. Much of that which exists is sound and usable. It is possible that the new orientation of the future will be based on the experience of the past as well as on the needs of the present and the future.

In relation to the changes which must occur, the Land Grant Colleges and Universities of the United States have much guidance to offer. Certainly the social mobility which these institutions have promoted by making a university education available to the sons and daughters of farmers is worthy of emulation. Similarly their success in promoting technology on the farm and their great social invention wherein teaching, research and extension are combined present principles even if the exact organizing scheme is not always feasible in Latin America. Perhaps Latin America and Anglo America have

something in common in that in both areas attempts are being made to improve the quality of basic scientific education and still train specialists competent to deal with the complexities of real problems. Both areas seem also to be concerned about those influences which help the student to realize his spiritual integrity. I know that as I go about visiting institutions both north and south, I see evidence that the mechanics of curricula, courses, equipment are often of less importance than the quality of enthusiasm among staff and students, the sense of responsibility and group spirit, and the evidences of continuity toward developing understanding. Incidentally, there is so much to be gained on both sides that we hope the plan initiated under Point Four auspices to relate American colleges with counterparts in Latin America will be continued and expanded. I have already mentioned the special role in this respect that should be played by Florida.

I hope that in the course of these observations there has been some argument for taking education and training more seriously into account as plans are drawn for the agronomic development of Latin America. To emphasize that point I want to close with a statement from Alfred North Whitehead which comes from his Aims of Education (1929). "When one considers in its length and in its breadth the importance of this question of the education of a nation's young, the broken lives, the defeated hopes, the national failures, which result from the frivolous inertia with which it is treated, it is difficult to restrain within oneself a savage rage. In the conditions of modern life the rule is absolute, the race which does not value trained intelligence is doomed. Not all your heroism, not all your social charm, not all your wit, not all your victories on land or at sea, can move back the finger of fate. Today we maintain ourselves. Tomorrow science will have moved forward yet one more step, and there will be no appeal from the judgment which will then be pronounced on the uneducated."

Florida's Role in Education and Training in Agriculture

Albert S. Muller*

Two special offices for organized handling of foreign students began to function at the University of Florida with the opening of the school year in 1952, when the number of such students was about 200. One is the Office of Foreign Student Adviser, which this year is handling as many new students as the total enrolled in 1952. The other is the Office of Counselor to Latin American Students in Agriculture, which at present is handling three times the number enrolled in 1952, and also more new students than the total for that year. Education in Agriculture is the aim of at least half of the Latin American students who come here. They represent about 20% of the student body in our college.

The establishment of this office in Agriculture was made possible through a three-year grant made by the Rockefeller Foundation, which was extended another two years. Last year maintenance of the office became a regular operation of the college. The experience, information and data accumulated by this office during six years provide background for discussion of the role of Florida in Education and Training in Agriculture as regards Latin America.

Florida's role in interamerican agricultural relationships is one of long standing. A summary of that role, as developed during the 30's was given at the general meeting of this Society in December, 1941, by Dr. R. S. Atwood; he predicted that future prosperity in all the Americas would depend on the development of a mutually advantageous agricultural program. He stressed, even then, how important it is for development in Latin America to be channeled in the mutual interests of the Western Hemisphere, and not diverted elsewhere. The development of Florida's resources has been and always will be interrelated with development of adjacent tropical areas. Because of its proximity to Latin America Florida is one of the best known states. Its cattle, pastures and crops, and the conditions under which they are produced, approximate more those in Latin America than in any other area of our country. The contribution of our Agricultural Experiment Stations are well known in Latin America and widely

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incorporated in agricultural development programs, both local and ICA-sponsored. These are reasons enough to attract many students to our campus.

Agricultural and Cultural Attachés in American Embassies and also educational officers of ICA (International Cooperation Administration) services recommend Florida to increasing numbers of students desiring to study Agriculture in the United States. In addition, we receive students, selected by various governments to study here, all expenses paid. The International Institute of Education sends us scholarship students every year to major in our department of Agricultural Education to prepare better teachers for national Schools of Agriculture and secondary schools with agricultural programs. Private foundations are increasing the number of fellowships for agricultural study at Florida. Students, returning to their own countries, or writing to their friends, plus our own professors travelling in Latin America, make Florida known to many prospective students. This is indicated by references in many initial inquiries about study in Florida, which arrive in constantly increasing numbers at the Dean's office and other offices concerned with admission.

Only about half of our students come on family funds, very few from wealthy backgrounds, and there are always some requiring part-time employment to make ends meet. We must be prepared for ever-increasing numbers of students from Latin America, particularly at the graduate level, since now undergraduate training in many countries provides adequate preparation for advanced study. An advanced degree from the United States is now a consideration of great importance to professional men entering the rapidly expanding governmental programs in agriculture. More and more scholarships are available down there; transportation costs to Florida are lower and overall living expenses in Gainesville for students are lower than in many other places.

Letters in reply to inquiries of prospective students are written in the student's own language, which helps to create greater confidence in boys thinking about coming to a new land to study. The result is that the student begins his long journey to Florida feeling that a friend will be waiting for him when he arrives. He is actually met on arrival in most cases, receiving a welcome in his own language and personal attention. During intervals between general orientation meetings, especially prepared by the Foreign Student Adviser and his collaborators, there are periods reserved for individual counselling in the College of Agriculture. During these interviews the students are encouraged to talk about themselves, their backgrounds, their countries, and personal objectives, in their own language. This establishes good relationships and furnishes material for more effective academic counselling. Full consideration can then be given, not only to the requirements of the College of Agriculture but also to the individual needs and preferences. During these talks, climatic and agricultural conditions at home are also discussed which helps in making up an adequate overall program of study. Preliminary schedules are organized for approval by department heads and other advisers, which prepares the student for smoother departmental inter-

views, where final agreement on schedules can be reached more easily. Time is saved and frustration avoided during registration by having old students accompany new students throughout the whole process. Latin American students are provided with angloamerican roommates for their mutual advantage.

Subsequent counselling during the semester includes discussions on academic progress, guidance in study methods, library use, relationships with professors, and guidance as to where and how to get help on personal problems. Most of these latter problems are taken care of at the Office of the Foreign Student Adviser. They include such matters as health, discipline, family troubles, social relationships, immigration problems, finances, employment and scholarship needs and so on. Our own office becomes the students' office, a place to come to between classes. Here there is available abundant technical and social reading material from the students' own countries. Here, students from various countries can exchange valuable information on many subjects and join with the counselor in discussions whenever they so desire. Opportunity for individual consultation is always readily available, enhanced by the fact that students frequent the office on their own initiative. Rarely does the counselor have to resort to calling in a student.

The effective operation of our program depends on close association with the Dean's office, the office of the Provost, Foreign Student Adviser and Admissions. Participation in meetings of the Interamerican Committee of the School of Interamerican Studies and the work of the Foreign Student Committee brings university-wide support to our program. Our professors are always ready to cooperate in regard to progress reports on Latin American students, to discuss with the counselor-students' problems or to talk with the students, themselves. Curriculum plans and scholastic records are kept in the office for each student, as well as a file of personal data. The average number of individual interviews per month is 70, this average being tripled in the first month of each semester, and doubled the last month of a semester. Yearly totals of interviews exceed 1100. Included in the total are the frequent interviews with angloamerican students and staff members who come to get all kinds of information on Latin America, or to obtain reading materials or to discuss job opportunities and living conditions in various countries.

Florida has provided education in agriculture to students from every Latin American country except Argentina. Over 20 students have come in the last five years from each of 4 countries; these are Costa Rica, Colombia, Cuba and Honduras. The 62 students, who are enrolled this semester, come from 14 countries. Animal Husbandry comes first in their choice of majors, not much difference being shown in the number majoring in Agronomy, Soils and Agricultural Engineering. Horticultural departments, Dairy and Poultry have fewer majors, and only a few select Entomology, Plant Pathology and Food Technology. Nevertheless, the course offerings of these latter named departments are considered essential electives by most Latin American students, as are certain Forestry courses by some. Only one has majored in Forestry, obtaining his degree in that school. Botany pro-

vides required courses and a useful elective in Vegetational Plant Geography of the Americas.

In a number of departments, instruction in Agriculture in Florida parallels instruction in Latin America, as to basic materials; animal breeds and pastures are the same; field, vegetable and fruit crops are the same; many diseases and insects are the same or likely to be invaders here or there. In Plant Pathology there is a specific course in Diseases of Sub-tropical and Tropical Fruits; in Fruit Crops courses in Major Tropical Fruits, also Minor Tropical and Sub-tropical Fruits, in addition to the Citrus courses; in Soils there is a course in Tropical Soils. There are many good electives in other Colleges of interest to Latin Americans, for example, business courses, economics, sociology, journalism, effective writing and typing. Special sections are available in a course in the Speech department for those foreign students who need improvement in speaking English.

Our agricultural library facilities provide much material of value on Latin America, including the library of Dr. David Fairchild and contributions of Dr. H. H. Hume, plus many government publications. In addition there are journals of agricultural and scientific societies of Latin America. Our experiment stations are working on dozens of projects of direct concern and interest for Latin American students, who will have to face the very same or similar unsolved problems in their own countries.

In the last five years 63 Latin American students have obtained the B.S. degree in Agriculture at Florida. Of these, 12 are now in graduate schools, 4 here and 8 elsewhere. One of our graduates has obtained his Ph.D. here, one elsewhere; 7 the M.S. and 2 the M. Ag. degree at Florida. We have been very successful in obtaining follow-up information on our graduates. We can account for the present activities of 68 of them. We are especially proud 16 of our graduates who have become teachers in agricultural schools in 7 countries. In 8 countries there are 17 graduates employed in governmental agricultural services, chiefly in Extension, 2 holding positions of Director. The number engaged in private farming operations, including Dairying and Beef Cattle production is 17 in 9 countries, and 6 are employed by firms dealing in agricultural products, machinery, and processing. One of the reasons why we have such good follow-up information is that our graduates rely on us for more help after returning home. We receive from them frequent requests for literature, references, contacts, personal recommendations, possible job openings, aid in pursuing graduate work, and specific information on a wide variety of agricultural matters. A considerable amount of correspondence arrives at the office of the Agricultural Experimental station from students, farmers, governmental agencies, institutions and libraries, the translation of these letters written in various languages, being handled by this office.

With respect to scholastic achievement, the record of our Latin American students is outstanding. In the last five years 8 have graduated with Honors and 6 with High Honors, out of the total of 63. These 14, members of university wide honor societies, were also elected to Alpha Zeta, the undergraduate honor fraternity in Agriculture.

as have been 6 others, plus 5 presently enrolled. A Costa Rican student obtained first place in his graduation class of 82 this year. Only two playboys have appeared and disappeared accordingly.

The International Cooperation Administration has selected Florida as the right place to send 74 Latin American students in recent years for one or two semester programs of study. All of these students have been on leave-of-absence from positions in the agricultural services of their countries, including posts in extension, investigation and administration. One has resigned after returning to work in a private cattle enterprize. No students have come from Argentina or Venezuela under this program. Nevertheless, the government of Venezuela has sent us 3 students from its own technical services on two-year scholarships.

A large number of agricultural technicians, extension workers and others from Latin America are sent us by ICA for training periods of 3 weeks to 3 months, here at the University or with Extension agencies or at our experiment stations, or combinations of these localities. Including even shorter time visitors, the total number of such trainees has reached 227 in the last five years. Among such visitors have been Ministers of Agriculture and a number of Directors of Experiment Stations and Extension Services. University presidents, deans, professors and also architects for new university programs have visited us. The contract between Costa Rica and our university, under ICA auspices, has resulted in our receiving more students, trainees and visitors from Costa Rica than from any other country.

We believe unreservedly that participation in a program of interamerican relationships brings mutual benefits. The student, today, becomes a valuable collaborator, tomorrow, who is prepared to contribute much, not only to his alma mater, but also to the State of Florida. Florida can take pride in having been a long-time leader, not a follower in contributing to the development through education of the great natural resources of its adjacent neighbors. The training of youth is but a beginning. The establishment of a strong center for research in basic tropical problems should be the next step, since most of the neighboring countries are not yet capable of carrying on research at high levels. This type of research will be of direct benefit to Florida.

If Europe has been our first line of defense in the past, Latin America may be just that in the future. Our appalling neglect of that area in the past could result in its being our weakness. Frank appraisal of the Nixon episode in Latin America clearly indicates how much more we shall have to do to insure ourselves a sound line of defense to the South of us. May Florida continue and intensify its already significant efforts in the field of interamerican relationships.

Cacao Soils

F. Hardy[1]

INTRODUCTORY

In taking the broad view which is necessary in a balanced approach to cacao soils, we must differentiate at the outset between *soil fertility* which solely concerns soil-nutrients and *site productivity* which concerns all the growth factors of the environment that determine the size of the crop. These ecological factors include both atmospheric and soil factors. Among the atmospheric factors are air-temperature, rainfall, humidity, wind and radiant energy (light), and among the soil factors are root-room, water-supply, air-supply, nutrient-supply, harmful factors and soil-temperature. The importance of considering all of these factors in attempting to identify limiting factors to growth and production in tree-crops such as cacao cannot be overstressed. This is the *ecological approach* and its chief tenet is that "the soil, the plant and the atmosphere are components of a single system."

Temperature: Cacao is particularly sensitive to air temperature. The limits for successful cacao cultivation are bounded by latitudes and altitudes within which the monthly mean daily maximum and minimum temperatures are 86° and 70° F. respectively. Attempts to grow cacao at higher or lower temperatures than these have not proved to be economical. Flower-formation is inhibited by temperatures below 72° F. (1) and reproduction practically ceases when the mean monthly temperature falls below 60° F. (2) Furthermore, the chief disease of cacao ("Black pod," *Phytophthora palmivora*) spreads rapidly at temperatures below 60° F. At the other end of the scale, bud-bursting and leaf-flushing become too frequent and may either debilitate the tree or make it more susceptible to pests and diseases when the mean daily range of air temperature exceeds 86° F. (3) These temperature relations confine the cacao industry to latitudes 15° north and 15° south of the equator and altitudes below 2000 ft., within this tropical belt.

Rainfall: Cacao requires sufficient rainfall, in the absence of a permanently-high water-table and of irrigation, to provide an excess over

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potential evapotranspiration which, within the cacao belt, lies between four and five inches per month, or 48 and 60 inches a year. Cacao cannot withstand drouths of over three to four months' duration with monthly rainfall less than about two and-a-half inches, unless there is a high water-table. Nor can it withstand long periods of restricted soil aeration caused by water-logging when it is grown in compact, fine-grained, impermeable soils, exposed to continuous rains.

Humidity and Wind: Low atmospheric humidity and high winds greatly accelerate evapotranspiration which, in cacao, soon causes stomatal closure, (4) and photosynthesis in consequence is greatly diminished. For these reasons, cacao is usually grown under shade in fields protected by wind-breaks, but both overshading and undershading must be strictly guarded against.

Light: Apart from the heating effect of the sun's radiant energy, which partly decides the rate of transpiration, light is essential for the photosynthesis of carbohydrate. In the case of cacao as compared with other tropical crop-plants, photosynthesis occurs at a low rate, even when the plant is grown in full sunlight. When water-shortage does not occur, the movements of the leaf-stomata are controlled by light but when the supply of available soil water falls below a certain critical value, the stomata quickly close, even when the intensity of light is high.

GOOD AND BAD CACAO SOILS

The accompanying diagrams (Figures 1 and 2) depict the main characteristics of good and bad cacao soils. (5)

(1) *Root-room:* The depth of root-penetrable soil should be at least five feet. There are three main causes that limit rooting-depth in "bad" cacao soils, shown in Fig. 2: d, e and f. They are, (i) hard-pan (impervious parent material, clay-pan) (ii) too-shallow soil profile (iii) high water-table. The presence of fragments of parent rock, quartz-gravel, ironstone-gravel or hard ferruginous concretions does not prevent root-penetration provided the materials are only sparsely scattered throughout the profile and do not occur within the surface foot layer (Fig. 1; b,c,d,e).

(2) *Color:* Cacao soils that are red or reddish-brown in color below the humic horizon are usually better than those that are pale-colored or grey or white, because they are obviously less leached, and therefore likely to contain a large concentration of nutrients, though this is not an invariable rule. Red and brown colors (hematite) imply complete oxidation of iron oxide and therefore mean good drainage and good soil-aeration. Yellow colours are associated with constantly moist conditions conducive to a high degree of hydration of ferric oxide (Limonite). Olive-green color is due to basic carbonates, implying the occurrence of calcareous parent rock. Blue-grey and green-grey colors are due to ferrous oxide and imply imperfect or impeded drainage. Ashy-white appearance denotes complete removal of iron oxide, generally by excessive lateral water movement, as on slopes.

Mottled, speckled or streaked coloration, in red, brown, yellow or sepia-black colors, implies impeded drainage if it starts at about the

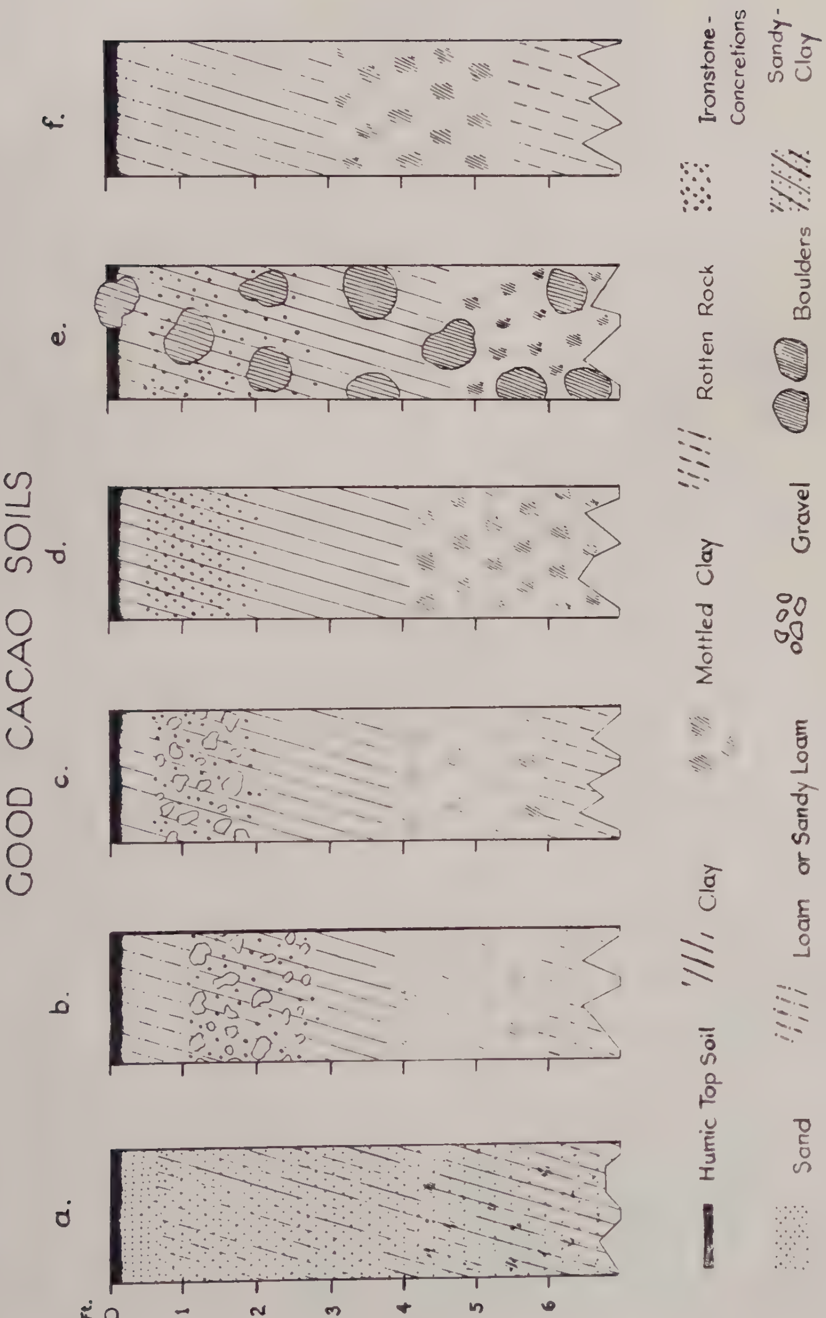
GOOD CACAO SOILS
a.
b.
c.
d.
e.
f.
ft.
0
1
2
3
4
5
6
Humic Top Soil
Clay
Mottled Clay
Rotten Rock
Ironstone - Concretions
Sand
Loam or Sandy Loam
Gravel
Boulders
Sandy - Clay

Figure I.

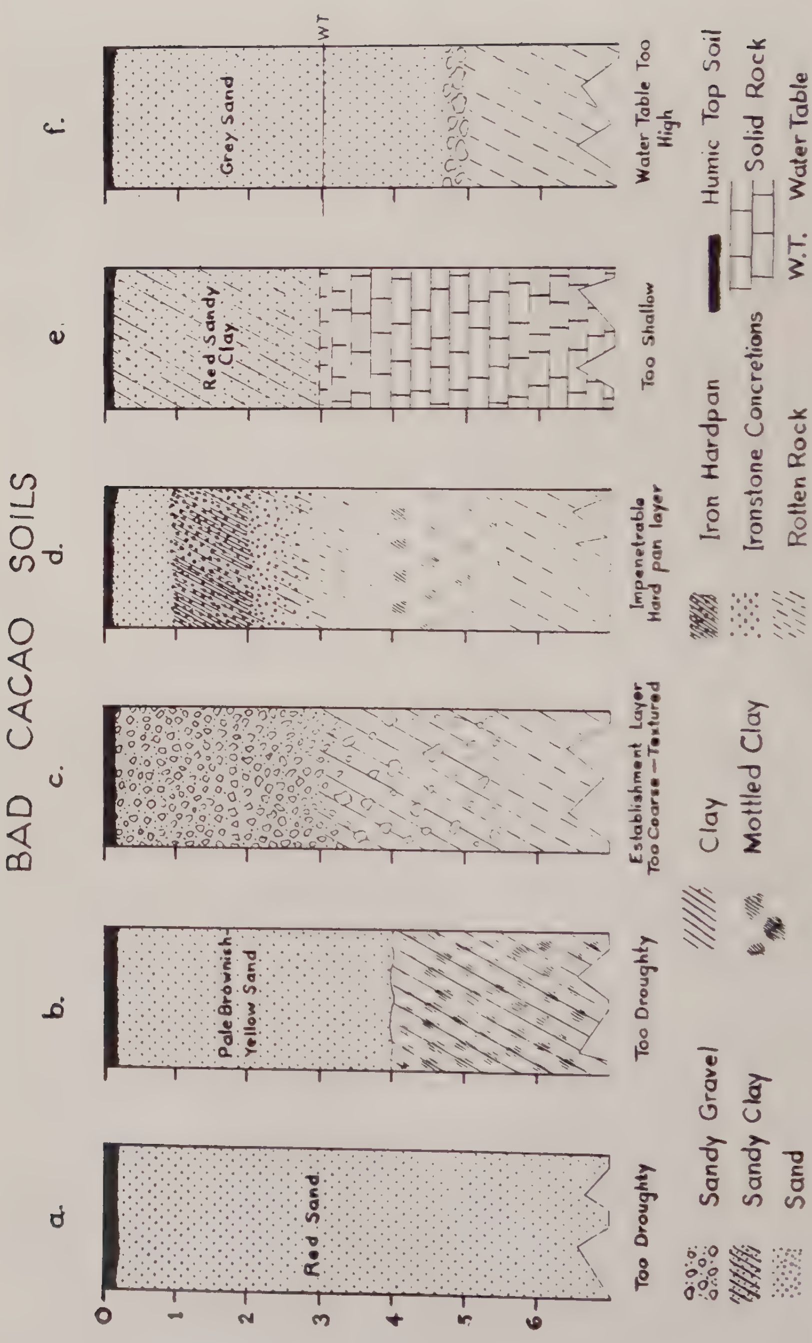
BAD CACAO SOILS
a.
b.
c.
d.
e.
f.
0
1
2
3
4
5
6
Red Sand
Pale Brownish Yellow Sand
Red Sandy Clay
Grey Sand
WT
Too Droughty
Too Droughty
Establishment Layer Too Coarse—Textured
Impenetrable Hard pan layer
Too Shallow
Water Table Too High
Sandy Gravel
Sandy Clay
Sand
Clay
Mottled Clay
Iron Hardpan
Ironstone Concretions
Rotten Rock
Humic Top Soil
Solid Rock
W.T. Water Table

Figure 2.

three-inches depth, imperfect drainage if it starts at about the two-foot depth, and free drainage if it only occurs below the four-foot depth. The background color in mottled soil is blue-grey ("gley") owing to the presence of ferrous oxide in variable quantity, depending on the degree of iron segregation. Grey gley becomes more and more conspicuous with depth in badly-drained cacao soils.

Black and brown coloration in the surface soil usually indicates the depth of humic penetration but its color intensity cannot be accepted as a measure of organic content since, in red soils common in the tropical cacao belt, humus apparently has a pale-brown color. Intense blue-black humous coloration is associated with poor drainage (swamps and marshes) and is usually accompanied by high acidity and a peculiar waxy and sticky kind of humus.

(3) *Texture and structure:* Good cacao soils comprise aggregated clays and loamy sands. The presence of large amounts of gravel or coarse sand in the subsoil is an undesirable feature in cacao soils, unless the water-table is fairly high. Uniform coarse sandy soils (particle size, 2.0 to 0.5 mm. diameter) although they allow easy root-penetration, are unsuitable for cacao-growing unless their nutrient status is good and the rainfall is high and continuous (Fig. 2, a,b,c). They are too drouthy. Clayey cacao soils are usually the best, provided they are aggregate-structured (small-nut) and stable under constant wetting, drying and rewetting.

An ideal cacao soil has a total pore-space of about 66 percent by volume, of which 33 percent is occupied by air (non-capillary pore-space) after the soil has been wetted and allowed time to drain, and 33 percent is occupied by firmly-held water (capillary pore-space). Its apparent specific gravity (bulk density) is 0.9, assuming that the true specific gravity of the soil material is 2.65 which is that of quartz and of kaolinite. Soils whose apparent specific gravity is less than 1.0 usually have highly-satisfactory porosity characteristics favouring rapid root-growth, whereas soils whose apparent specific gravity is greater than 1.75 (sands) or 1.46 (silts) or 1.63 (clays) are generally too compact to permit easy root-penetration. (6) These values correspond to total pore-space values of 35, 45 and 38 percent by volume, respectively.

The characteristic features of the cacao root-system, as developed in different kinds of soil profiles having different causes of root-impedence are shown in Figure 3. The best root-system is that depicted in profiles (b) and (d) consisting of well-structured clay. Impedence to root-growth by pieces of iron-pan and ferruginous concretions is shown in (a) by shallow parent rock in (c) and (d) and by high-water-table in (f) and (g).

(4) *Consistency:* Cacao soils that are loose, crumbly, soft and plastic when moist are better than those that are compact, coherent, hard and rigid, because they permit easy root-penetration, since they have low apparent specific gravity which implies high porosity. Undoubtedly the best consistency and the best structure most conducive to good aeration and rapid root-growth is that possessed by highly humic soils, whether they be sands, silts or clays.

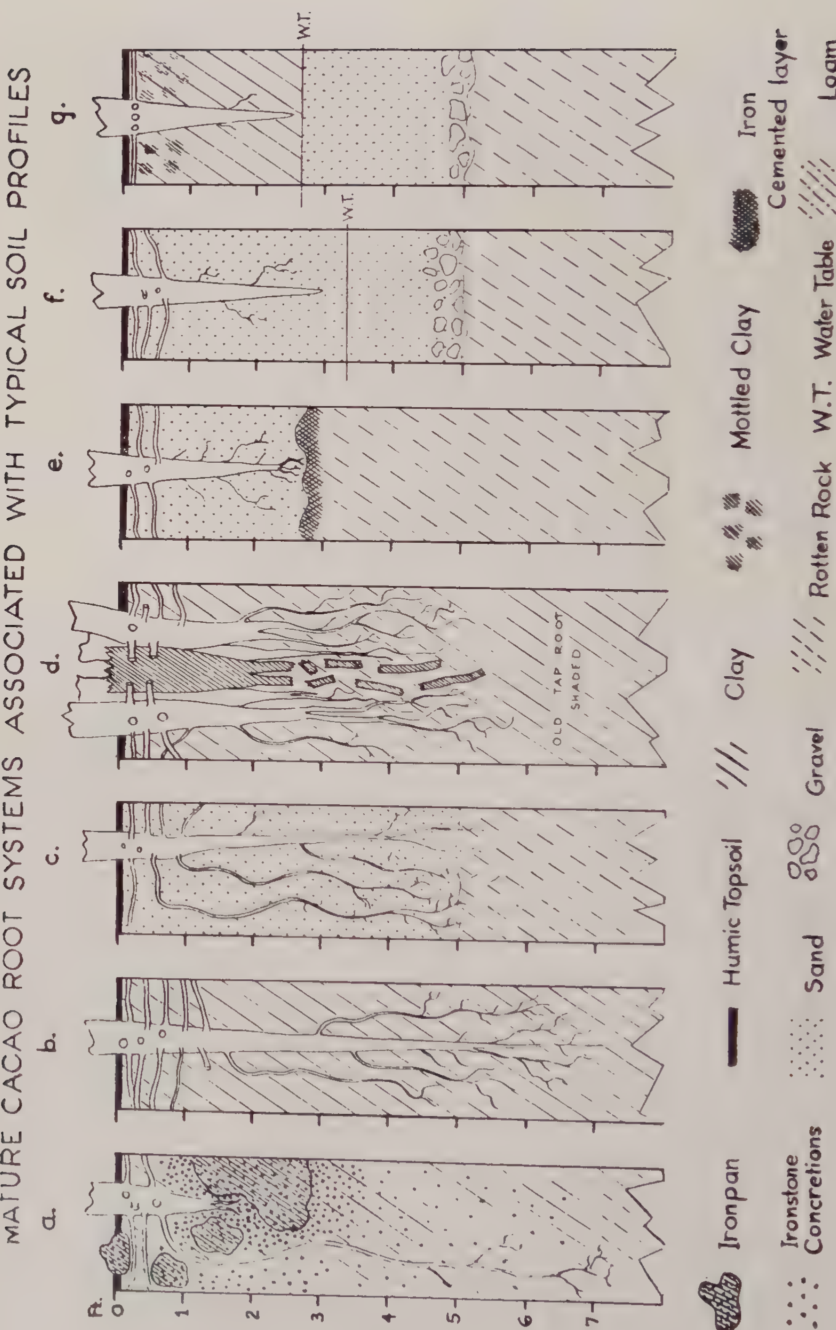
MATURE CACAO ROOT SYSTEMS ASSOCIATED WITH TYPICAL SOIL PROFILES
a.
b.
c.
d.
e.
f.
g.
Ft.
0
1
2
3
4
5
6
7
W.T.
W.T.
OLD TAP ROOT SHADED
Ironpan
Humic Topsoil
Clay
Mottled Clay
Iron
Ironstone Concretions
Sand
Gravel
Rotten Rock
W.T. Water Table
Cemented layer
Loam

Figure 3.

CACAO NUTRITION

The nutrient status of cacao soils, considered in profile, varies greatly. It is closely associated with organic matter content, not necessarily solely with the total amount of organic matter present and its depth of penetration, but chiefly with the degree of decomposition as indicated by C/N ratio. Thus it has been established by statistical analysis of laboratory data that yields of dry cacao beans in Trinidad, Tobago and Grenada are positively significantly correlated with the magnitude of the C/N ratio. Freshly-fallen leaf-litter and soil organic matter derived from it which have not become too much decomposed and leached, contain large stores of nutrients in readily-available form. If not constantly replenished, however, the C/N ratio of the top 6-inch layer of soil falls to values below 10 and the store of bases and of phosphorus rapidly diminishes, though the soil may still be capable of supplying nitrogen. The successful application of chemical analysis to the study of cacao soil fertility depends on two pre-requisites, namely, (1) the measurement of rooting-depth and (2) the establishment of standards of comparison for the different nutrient entities and for organic matter content.

(1) *Root-room effect:* Consider two sites, A and B, supporting cacao trees of exactly equal age and size but assume that the root-room at A is twice as great as that at B. Since the trees have reached the same stature, the *concentration* of nutrients (expressed as grams percent) in the soil at B must be twice as large as that in the soil at A, because presumably it has required the same *total* amount of nutrients to produce each tree. Consequently, a 6-inch soil sample collected at B would give, on chemical analysis, results twice as high in magnitude, reckoned on a weight percentage basis, as a 6-inch soil sample collected at A, and it might therefore be erroneously concluded that the soil at site B was capable of producing a tree twice the size of that which site A could produce. This illustrates a common error in the application of soil analysis in attempting to compare fruit-tree soils possessing markedly different physical features.

In sampling cacao soils in the field, the best procedure is to excavate pits of convenient dimensions (for example, 3 x 3 x 6 feet) near to typical cacao trees so as to expose a vertical section of the root-system including the tap-root. The profile is then divided up by horizontal marks into horizons duly observing significant changes in color, structure, texture and consistency. In the case of cacao soils which show no sharp subdivisions, the sampling depths are arbitrary, the smallest being nearest the surface, thus: — 0-1½, 1½-3, 3-6, 6-12, 12-18, 18-24, 24-36, 36-48, 48-60 and 60-72 inches (10 samples). Constant-volume samples are taken within each layer for the determination of specific gravity (pore-space) and bag-samples are collected from each layer for chemical analysis in the laboratory.

(2) *Standards of comparison:* Standards of adequacy for organic matter and "available" nutrients can only be erected after a large number of soil analyses have been made of samples collected from cacao fields having known yielding capacities and from the plots of

field manurial experiments in which yields have been measured. The following table (Table 1) presents some averaged results of the chemical analysis of typical West Indian and West Africa cacao soils (0-6 inch samples) compared with standard values used at the Imperial College of Tropical Agriculture, Trinidad.

Discussion: The cacao soils of the West Indies are much less sandy than those of West Africa and they contain more organic matter in the surface 6 ins. layer. The C/N ratio is significantly higher for the "good" cacao soils (mean 10.7) than for the "bad" (mean 9.0). The content of exchangeable bases is about twice as high in the West Indian soils as in the West African soils, and about twice as high in the "good" soils as in the "bad."

Magnesium has been proved to be a particularly important nutrient for cacao. (7) Exchangeable magnesium content should not be less than one-quarter that of exchangeable calcium for balanced nutrition, and the sum of the contents of exchangeable calcium *plus* magnesium should not be less than about 25 times that of exchangeable potassium. Excess of potassium suppresses the uptake of magnesium and zinc and the characteristic deficiency symptoms of these elements appear in the leaves.

Available phosphate, like the exchangeable bases, is about twice as high in the West Indian soils as in the West African soils, and about twice as high in the "good" soils as in the "bad." The West African "bad" soils are highly acidic but the rest seem mostly not to be particularly acid, implying freedom from toxic concentrations of aluminum, iron and manganese.

Nutrition and Shade: Influenced by the fact that cacao is a component of the lowermost storey of the Tropical Rain Forest, planters up to now have generally planted shade trees in the cacao fields. In West Africa, cacao is grown as a peasants' crop directly in the forest. Recent experiments in Trinidad have shown that cacao can be grown satisfactorily without shade, at least after the early establishment stage, that is, about five years from the time of planting, provided the soil offers sufficient root-room and its nutrient status is high, or fertilizers are liberally used. (8,9)

Under high light intensity or full sunlight, unless the products of photosynthesis are rapidly transported and at once utilized for manufacturing protein and other food stuffs, carbohydrates accumulate to such an extent as virtually to poison the plant. In order to use up these products, a large supply of nutrients is required and this may only be ensured when the tree is growing in a physically-suitable soil in which the nutrient status is augmented by manuring. When permanent shade is lacking, provisional shade must be provided for young cacao under all circumstances until self-shading by the developing leaf-canopy has been attained.

Cacao grown under artificial shade consisting of leguminous trees does not respond to nitrogenous fertilizers though it may respond to phosphatic and potassic materials. This is partly because the litter from leguminous trees contains especially large amounts of nitrogen and contributes up to about 40 lb. of the element per acre per year.

TABLE 1.—ANALYTICAL DATA FOR "GOOD" AND "BAD" CACAO SOILS

(Topsoil, 0-6 ins.)

Locality	I.T.*	Reaction	Org. Matter	Total N	C/N ratio	Exchangeable bases: Reaction	Exchangeable bases: Ca	Exchangeable bases: Mg	Exchangeable bases: K	Ratios: Ca/Mg	Ratios: (Ca+Mg)/K	Avail.† P_2O_5
		pH	%	%		pH	Mg	eq.	100g.			p.p.m.
						GOOD SOILS						
West Indies												
Trinidad	36	6.6	4.8	.28	9.8	6.4	20.5	5.8	0.44	3.5	59.8	42
Tobago	32	6.7	4.7	.24	11.1	----	----	----	0.21	----	----	63
Grenada	37	6.9	3.9	.21	10.7	6.1	17.7	8.8	0.70	2.0	37.9	75
West Africa												
Ghana	9	6.4	2.8	.14	11.1	7.3	10.5	2.2	0.41	4.8	31.0	25
Nigeria	7	6.5	2.4	.13	10.7	----	----	----	0.31	----	----	--
						BAD SOILS						
West Indies												
Trinidad	34	5.6	3.3	.25	7.7	5.9	6.3	5.5	0.32	1.1	36.9	25
Tobago	37	6.6	3.4	.21	9.1	----	----	----	0.14	----	----	24
Grenada	41	6.6	3.8	.23	9.4	5.6	6.3	7.9	0.50	0.8	28.4	45
West Africa												
Ghana	7	5.8	1.5	.09	9.7	5.3	4.7	0.9	0.29	5.2	19.3	18
Nigeria	2	4.8	1.6	.07	(13.4)	----	----	----	0.15	----	----	14
STANDARDS OF COMPARISON												
Limits of adequacy	30	6.0	3.5	.22	9.0	---	8.0	2.0	0.24	4.0	25.0	40

*Index of Texture, based on sand content and sticky point, provides a measure of degree of colloidatity: clays, sands and loams I.T. 0-30; silts and clays I.T. 30-60.

†Truog's method; extraction with 0.002 N-sulfuric acid.

Cacao grown without shade usually benefits greatly from treatment with nitrogenous manures.

It must constantly be borne in mind that tropical tree-crops such as cacao and their shade trees when properly managed and treated with manures, fertilizers and amendments, through the large quantities of litter that they constantly add to the soil and the great abundance of roots that they produce therein, tend adequately to maintain the organic status of the soil, in spite of the high rate of decomposition of soil organic matter at high temperatures.

CACAO CROP STUDIES

Fertilizer experiments: Based on chemical analysis of soil samples, a large number of field experiments with standard NPK fertilizers have been carried out in the West Indies on old cacao. The results have been most disappointing. Failure has been traced to two main causes, namely, soil heterogeneity and heterogeneity of the tree population. Soil heterogeneity has been shown mainly to concern *physical* conditions, particularly soil aeration and root-room. Results obtained by the periodic determination of soil moisture at selected sites, and by the analysis of soil-air samples, (10) have shown that temporary waterlogging occurs frequently in cacao fields. This finding agrees with that recorded for apple orchards in New York State, U.S.A., (11) and was confirmed by root studies of the cacao-tree growing in different soils in Trinidad. (12)

Root growth: Roots appear to "follow the water content" in well-aerated soils. Thus during dry spells when the moisture content of the surface layer falls below field capacity level because of continued evapotranspiration, while that of the subsoil layers remains at or above field capacity, cacao roots grow downwards into the moister soil. During wet spells or continuously showery weather they tend, however, to stay in the surface layer, or actually to grow over the soil surface beneath the decomposing leaf-litter, forming a distinct root-mat. At the onset of the rains, the roots of cacao trees planted in heavy clay soils grow downwards through cracks formed during the dry season. (10).

Tree heterogeneity is responsible for the fact that only a small proportion of the pickets in a field respond to fertilizers by producing more pods. Up to 50 percent of the tree population of a cacao field, even on good soil, may not bear any fruit, and half of these trees owe their lack of fruitfulness to damage by cutlass-wounds, falling shade trees, land-slides, pests and diseases, or to unsuitable strains of cacao plants.

In recent years, the replanting of fields with clonal cacao cuttings from selected high-bearing strains has revived interest in the use of fertilizers and many new manurial experiments have accordingly been started. Nevertheless, the marked deterioration that has affected the soil of many areas where old cacao has been felled for replanting, both in the West Indies and in West Africa, has greatly reduced the possibility of high production in the future.

A high degree of correlation was established in one of these new fertilizer experiments between the trunk-girth of 3½ year old cacao trees and average yields of cacao during the three succeeding cropping seasons. This important findings stresses the need for careful nursery work and for efficient field management during the establishment phase of cacao growing. (13)

Soil deterioration in old cacao fields and in abandoned areas that have been cleared and left for replanting has been traced to loss of organic matter brought about either by surface erosion or by a diminishing supply of leaf-litter owing to lessened growth and continuous cropping. (14) It has affected bad soils more than good so that it may no longer be profitable to replant cacao on poor soil, particularly where the "poorness" concerns physical rather than chemical properties.

Soil renovation in the future when old fields are being replanted with high-bearing clonal cacao or hybrid seed, may involve soil cultivation with tillage implements, accompanied by round-ridging of beds and the construction of field drains. (15) Appropriate systems of management, involving both soil cultivation and the use of manures, mulches, fertilizers and amendments, have not yet been elaborated and tested, and the search for exploitable virgin forest land where cacao may be planted within the tropical belt still goes on.

PEDOLOGICAL ASPECTS OF CACAO SOILS

The most suitable soils occurring in the cacao belt, arranged in order of preference, are:—

(1) *Regosols:* Soils developed over fresh, loose, deep volcanic fragmental rocks, particularly volcanic ash. These are fairly common in Central and South America.

(2) *Alluvial soils* developed over unweathered deposits such as fresh volcanic ash and fresh rock-waste periodically rejuvenated by addition of humic soil washed off the slopes; ie. "living alluvium." These occur in practically all cacao-growing countries.

(3) *Lithosols:* Soils developed over partly-weathered and fresh rock, exposed by erosion on steep declivities, provided the rock contains suitable minerals (See (4)). They are not yet common.

(4) *Immature Latosols:* Reddish-Brown and Red Latosols, developed over sub-basic and basic igneous and metamorphic rocks such as granodiorite, monzonite, andesite and hornblendic gneiss. These comprise the better cacao soils of West Africa, West Indies and Brazil. They are dark-grey or black rocks, since they contain a high proportion of ferromagnesian minerals (hornblende, augite, olivine). Being less nutrient rich than the other groups, however, they may require fertilizer treatment for high production.

(5) *Rendzina and Brown Forest soils* developed over certain limestones and marlstones, particularly when they contain glau-

conite, as does the parent rock of the famous "Chocolate soil" of Trinidad. Unfortunately, when deeply eroded, the parent calcareous rock may cause lime-induced chlorosis.

Other pedological soil-groups such as immature hydromorphic soils (Humic Gley and Planosol) are also suitable for cacao production because of their favourable water-relations, but they need to be thoroughly drained and manured in order to give good yields.

SUMMARY

1. The ecological requirements of cacao for high production are stated. Temperature and rainfall are particularly important.
2. The distinguishing features of "good" and "bad" cacao soils are considered and illustrated by profile diagrams. Root-room, air-supply and nutrient-supply are especially significant in the growth of the cacao tree.
3. Averaged chemical analytical data for typical "good" and "bad" cacao soils are given in a table.
4. The effect of shade on the nutrient needs of cacao is considered, and the great importance of nursery and field management in the successful establishment of cacao is stressed.
5. The possible need of tillage and of manures, fertilizers and soil amendments in the rehabilitation of old cacao plantations is discussed.
6. The kinds of tropical soils most suited to cacao production are briefly described in order of importance.

LITERATURE CITED

1. P. de T. Alvim, "Correlacao entra Chuva, Temperature e Producao do Cacaueiro," *VI Reuniao do Comité Técnico Interamericano de Cacau*, 1956, Bahía, Brasil, pp. 133-136.
2. I. Ernholm, "Cacao Production of South America," 1948, Gothenburg, Sweden.
3. P. de T. Alvim, "Fatores que Controlam os Lancamentos do Cacaueiro," *VI Reuniao do Comité Técnico Interamericano de Cacau, 1956*, Bahía, Brasil, pp. 117-125.
4. P. de T. Alvim, "Stomatal Opening as Practical Indicator of Moisture Deficiency in Cacao," VII Conf. Interam. Cacao, Palmira, Colombia, 1958 (in the press).
5. C. F. Charter, "Cocoa Soils, "Good" and "Bad,"" W.A.C.R.I., Ghana, 1948, mimeographed circular.
6. F. J. Veihmeyer and A. H. Hendrickson, "Soil Density and Root Penetration," *Soil Sci.*, LXV, 1948; pp. 487-493.
7. C. F. Charter, "Nutrient Status of Gold Coast Forest Soils," Cocoa, Chocolate and Confectionery Alliance Conference Report, 1955, London, pp. 40-48.
8. D. B. Murray, "Climatic Requirements of Cocoa, with Patricular Reference to Shade," Cocoa, Chocolate and Confectionery Alliance Conference Report, 1955, London, pp. 17-22.
9. D. B. Murray, "Role of Shade and Fertilizers in the Cultivation of Cacao," *Agric. Soc. Trinidad and Tobago, Journ.*, LVII, 1957, pp. 193-207.
10. F. Hardy *et al.*, "Studies on Aeration of Cacao Soils in Trinidad (I)," *Trop.*

Agric., Trinidad, XIX, 1942, pp. 175-180, (II) *Ibid* pp. 215-223; (III), *Ibid.,* XX, 1943, pp. 13-24; (IV) *Ibid* pp. 51-56; (V) *Ibid;* pp. 89-104.

11. D. Boynton and W. Reuther, "Seasonal Variation of Oxygen and Carbon-Dioxide in Three Different Orchard Soils," *Proc. Amer. Soc. Hort. Sci.,* XXXVI, 1938, pp. 1-6.
12. F. Hardy *et al.,* "Root System of Cacao," *Trop. Agric.,* Trinidad, XX, 1943, pp. 207-220. Also "Some Soil Relations of the Root System of Cacao," *Ibid.,* XXXI, 1944, pp. 184-195.
13. T. A. Jones and G. K. Maliphant, "High Yields in Cacao Field Experiments and their Significance," VII Conference Interamericana de Cacao, Palmira, Colombia, 1958, (in the press).
14. F. Hardy, "Deterioration of Cacao Soils In Trinidad," *Report on Cacao Res.,* 1945-1951, I.C.T.A., Trinidad, 1953, pp. 83-88.
15. F. Hardy, "Productivity of Cacao Soils and its Improvement," *Trop. Agric.* Trinidad, XXX, 1953, pp. 135-138.

CONTRIBUTED PAPERS

Distribution of Microorganisms, Nitrate Production and Nutrients in the Profile of Lakeland Fine Sand and Related Soils.*

CHARLES F. ENO and HARRY W. FORD**

INTRODUCTION

The microbiological status of the deep, well drained, profiles of Lakeland fine sand and related soil types in the citrus producing ridge area of central Florida has not been studied. Interest in such a study developed following reports by Ford (6, 7) that citrus feeder roots are not confined to the surface four-feet of soil, as previously assumed, but can be found to depths below 17 feet. Frequently more than 50 percent of the feeder root system is below 30 inches in the soil.

In general, microorganisms are most numerous in the surface six inches of soil; they decrease rapidly with increased depth so that below about three feet only a relatively small number can be found. The magnitude of the population at various depths may depend upon the soil type, nature of parent material, aeration, organic matter, nitrogen content, moisture content, presence of toxic materials, crops grown and their sequence, and seasonal changes (3, 4, 12, 14, 16).

Blue, et al (2) have shown that the numbers of microorganisms in Leon fine sand is influenced by factors other than depth in the soil profile. The A_2 horizon (9- to 12-inch depth), with organic matter content and exchange capacity, had smaller quantities of nutrients and fewer microorganisms than did other parts of the profile. Increasing the amount of fertilizer did not significantly increase the nutrient concentration or numbers of microorganisms in the A_2 horizon. In spite of frequent saturation with water, the 12- to 30-inch depth showed increased numbers of microorganisms, exchange capacity and nutrient concentrations, particularly nitrate nitrogen and potassium.

The influence of vegetation on bacterial numbers in soils was shown by Waksman (15) in a comparison of garden, orchard, meadow and forest sites. Generally, he found the largest number of bacteria at a depth of one inch in soils under shade the year round and a regular decrease in numbers occurred to a depth of 30 inches. Meadow soils had the highest count at one inch. Forest soil, though having a high organic matter and nitrogen content, gave the lowest bacterial count probably because of high acidity. The numbers were not neces-

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sarily governed by moisture content, organic matter or nitrogen content. Soil depth was found to influence not only the total number of organisms, but also the distribution of the various groups (17). For example, at one inch plate counts showed 91 percent bacteria and 9 percent actinomycetes, while at 30 inches bacteria accounted for only 35 percent of the population and actinomycetes 66 percent.

It has been suggested that toxic compounds removed from the organic matter horizon by leaching and deposited in the B horizon inhibit growth. Gray and McMaster (9) have submitted evidence to refute this theory by growing soil organisms satisfactorily on media containing extracts of the B horizon. Their results also indicated that the organic matter horizon is biologically the most active, as shown by carbon dioxide production, nitrification of soil nitrogen, numbers of bacteria and production of ammonia from urea. Based on several of their measurements, they estimated the activity in the mineral horizons (A_2 and B) to be less than 4 percent of the activity of the surface layer of organic matter.

Stewart and Greaves (13) studied the production and movement of nitric nitrogen in an irrigated soil to a depth of 10 feet and found as much as 20 pounds per acre at this depth. However, this was not a measure of nitrification at various depths for the nitrate may have been leached from surface horizons.

This work was initiated to evaluate the relationship of soil depth to the relative numbers of microorganisms, nitrate production and some related chemical properties.

METHODS AND PROCEDURE

The soils studied were predominantly Lakeland, Blanton and Eustis fine sands largely obtained from Polk County.

Soil samples were collected with a four-inch post hole auger using extension sections for the handle shaft. The hole was first enlarged with a six-inch auger to prevent excessive contamination from horizons above that being sampled. A blowtorch was used to flame the augers and the collecting tray prior to each sample. Soil was placed in one-quart ice cream containers. All biological studies were completed on field-moist soil and except for nematode counts were calculated on an oven-dry basis. Chemical analyses were based on air-dry weight.

Plate counts of the fungi and bacteria were made using rose bengal and soil extract agar, respectively. Nitrifiers were determined by the dilution method using three tubes per dilution and dilutions of 1 to 10^2, 10^3, 10^4, 10^5 and 10^6 (1). Total counts of nematodes were made on 150 cc. of moist soil using the technique described by Christie and Perry (5). Nitrate production was determined on 150 grams of soil incubated for 28 days at 28 degrees C. Treated soils contained 300 ppm. of nitrogen as ammonium sulfate. In the limed series the equivalent of 2 tons of $CaCO_3$ per acre six-inches were applied. All soils were adjusted to approximately one-half of their water-holding capacity prior to incubation. Nitrate was determined by the phenoldisulfonic acid method (10).

RESULTS AND DISCUSSION

Nitrate production data (Tables 1, 2 and 3) are divided into three columns in each case. The column labeled "N-treated soil" shows the total nitrate nitrogen produced in the soil to which ammonium sulfate was added. The "check soil" column records that produced from the nitrogen constituents of the soil. Data shown in the "difference" column, found by subtraction, theoretically is that produced from the added nitrogen.

The surface six-inch layer of these soils generally produced nitrate abundantly when a nitrifiable source of nitrogen was present, Table 1. Average total production of the "N-treated soil" was 211 ppm. nitrate nitrogen and ranged from 106 to 307 ppm.; 64 percent of the soils produced more than 200 ppm. Ninety-three percent of these soils had a pH higher than 5.5 prior to adding calcium carbonate in the nitrification study. This important variable in nitrate production, therefore, generally was not limiting the maintenance of an active population of the nitrifiers in these soils. The lowest production of nitrate was usually associated with low pH. This surface-soil nitrification study also compared samples obtained from spreading decline areas with that from areas not showing these symptoms, orange grove soil with grapefruit grove soil and tree drip-line soil with that from the middle-of-the-row. No difference in rate of nitrification could be detected between these paired samples. Tree drip-line samples had an average pH of 5.9 compared to 6.2 for the samples from the middle-of-the-row.

The remainder of this study involved a microbiological characterization of the soil in the root zone of citrus trees to a depth of 10 feet. Nitrate production was at a maximum in the surface five-inch layer of soil, Table 2. Compared to the surface soil, production in the lower horizons showed a striking decrease under laboratory conditions which were considered to be in the optimum range for moisture, pH, aeration and temperature. Nitrate production in the 5- to 10-inch horizon was 54 percent less than the surface rate; the rate progressively decreased to 1 percent at the 8- to 10-foot depth.

In order to more nearly duplicate field conditions, samples from five profiles were compared unlimed and with an application of calcium carbonate equivalent to 2 tons per acre, Table 3. Nitrification was predominantly a function of the surface soil when no lime was added. The "N-treated soil" data show that the 5- to 10-inch zone produced only 20 percent as much nitrate as the surface horizon and each of the lower horizons produced less than 4 percent of the surface rate. The shallow production in the unlimed soil is in striking contrast to the limed soil where considerable production of nitrate occurred to a depth of 30 inches. There is considerable evidence that the soils sampled in April (Table 3) were more active and to a greater depth than those sampled in December and February, Table 2. Significance can be attached to this difference only when consideration is given to the fact that spring temperatures are higher than those in the winter and the nitrifiers have been actively converting fertilizer and soil ammoniacal nitrogen to nitrate in the period just preceding the study made on the April samples.

TABLE 1.—A Summary of the Nitrification Status and pH of Surface Six-Inch Samples of Sixty-Seven Lakeland Fine Sand and Related Soils Under Citrus Production.

	Nitrate Nitrogen in ppm											
	5-10	11-15	16-20	21-25	26-50	51-100	101-150	151-200	201-250	251-307	Mean	Range*
	(Number of soil samples within each range of nitrate production)											
N-treated soil							8	16	34	9	211	106-307
Check soil	2	9	15	13	17	9	2				32	5-124
Difference						3	14	27	22	1	179	92-251

*Difference values not found by subtraction.

pH						
4.73-5.00	5.01-5.50	5.51-6.00	6.01-6.50	6.51-6.90	Mean	Range
2	3	16	24	22	6.18	4.73-6.90

TABLE 2.—Variation With Soil Depth in Numbers of Fungi and Bacteria, Nitrate Production, pH, Moisture Equivalent and Extractable Nutrients in Lakeland Fine Sand and Related Soils Under Citrus Production.

Soil Depth	Fungi	Bacteria	Nitrate Nitrogen Produced			Initial pH	Ammonium Acetate Extractable (pH 4.8)				Moisture Equivalent
			N-treated Soil	Check Soil	Difference		CaO	Na	K_2O	P_2O_5	
	Thousands /gram	Millions /gram	ppm	ppm	ppm		ppm	ppm	ppm	ppm	%
0-5″	42.6	3.17	224	24	200	5.74	568	12	41	42	3.05
5-10″	20.2	2.62	120	12	108	4.95	105	10	23	31	1.97
10-20″	11.0	2.20	68	6	62	4.50	32	7	17	26	1.72
20-30″	11.1	1.74	52	6	46	4.34	27	7	15	19	1.60
3-4′	7.9	1.53	20	3	17	4.38	19	6	14	15	1.50
4-6′	7.1	0.97	10	2	8	4.40	16	6	12	13	1.39
6-8′	4.7	0.68	8	2	6	4.42	15	5	16	9	1.44
8-10′	6.9	0.49	3	2	1	4.46	20	5	14	7	1.43

Samples obtained in two units on Dec. 27, 1954 and Feb. 28, 1955.

Nitrate production is an average of 18 profiles. All other data are an average of 13 profiles.

TABLE 3.—THE VARIATION WITH SOIL DEPTH IN NITRATE PRODUCTION AND pH IN LAKELAND FINE SAND AND RELATED SOILS UNDER CITRUS PRODUCTION.[1]
April 18, 1958

Soil Depth	Nitrate Nitrogen Produced (ppm) N-treated Soil	Check Soil	Difference	pH Initial	Final Check Soil	Final N-treated Soil
			(Unlimed)			
0-5″	116	15	101	5.7	6.0	4.3
5-10″	23	12	11	5.4	5.3	4.3
10-20″	5	4	1	4.8	5.0	4.7
20-30″	4	4	0	4.8	4.9	4.7
3-4′	2	4	−2	4.7	5.1	4.7
4.6′	3	3	0	4.8	5.3	5.0
6-8′	2	3	−1	4.9	5.4	5.0
8-10′	2	2	0	4.6	4.9	4.7
			(Limed 2 Tons/Acre Equivalent)			
0-5″	240	18	222		6.6	5.4
5-10″	171	10	161		6.5	4.9
10-20″	107	6	101		6.6	5.7
20-30″	79	6	73		6.6	5.9
3-4′	34	3	31		6.7	6.3
4-6′	22	4	18		6.6	6.5
6-8′	12	2	10		6.7	6.8
8-10′	5	3	2		7.0	6.9

[1]Average of five locations.

Data in Tables 2 and 3 indicate that a reduction in nitrate production is associated with the original soil pH, especially in the depths below 10 inches. Other factors are also involved since uniform additions of lime to samples from all horizons did not result in the same rate of nitrate production. A study of the apparent numbers of nitrifying organisms present in the soil, by a dilution technique, has shown that a considerable reduction occurs with soil depth, Table 4. One hundred thousand to a million or more organisms occurred in the surface soil. An average decrease of ten fold in apparent numbers of nitrifiers occurred in the 5- to 10-inch zone and again in the 10- to 20-inch and 3- to 4-foot zone; thereafter <100- to 100 occurred per gram of soil. Decrease in nitrifying organisms, therefore, was also associated with reduced production of nitrate. However, factors other than initial numbers of these bacteria were important in the depths to 30 inches because, with lime, nitrate production was equal to or higher than that produced in the unlimed surface soil. It is conceivable that low numbers of nitrifiers was the limiting factor at depths greater than about 4 feet, when consideration is given to the fact that very small amounts of nitrate were produced even in the limed soils.

Fungi, bacteria and nematode data, Tables 2 and 5, also showed a decrease in numbers of organisms with depth. Compared to the apparent numbers of nitrifiers, however, these two groups of or-

TABLE 4.—THE RANGE IN APPARENT NUMBERS OF NITRIFYING ORGANISMS PER GRAM OF SOIL IN THE PROFILE OF LAKELAND FINE SAND AND RELATED SOILS UNDER CITRUS PRODUCTION.

Soil Depth	Numbers per gram
0.5″	100,000 1,000,000, or more
5-10″	10,000 — 100,000
10-20″	1,000 — 10,000
20-30″	100 1,000
3-4′	100 1,000
4-6′	<100 ... 100
6-8′	<100 . 100
8-10′	<100 100

ganisms did not decrease as rapidly with depth. It must be recognized that plate counts involved a spectrum of organisms of varying requirements and, therefore, certain organisms may be more abundant in the surface soil while others may predominate at greater depths. Many changes can occur without an obvious change on the plates; this in itself limits the value of plate counts.

The nutrient status of the various horizons is indicated by the amounts extracted by ammonium acetate. Except for phosphorus, nutrient levels below the surface five inches of soil were generally low. Calcium, potassium and nitrogen (as indicated by nitrate produced in the check soils) did not decrease in the soil profile as rapidly as nitrate production. Moisture equivalent, Table 2, in addition to indicating water-holding capacity of these soils, also showed that the 0- to 5-inch horizon contained much more surface per unit volume of soil. Below five inches little change occurred in moisture equivalent. Quastel and Scholefield (11) have shown that nitrate production is controlled somewhat by the amount of surface in the soil. In some perfusion studies they were unable to initiate nitrate production in a "seeded" sand column while production increased in columns to which clay was added. The top horizon contains much more surface, probably as organic colloids, as these data and other reports (8) have indicated. Nitrate production, nevertheless, did not decrease at a rate proportional to the decrease in moisture equivalent.

These data show that despite the fact that pH, moisture, aeration and temperature were held in the favorable range for nitrification, it

TABLE 5.—TOTAL NEMATODES PER 150 C.C. OF MOIST SOIL FROM THE PROFILE OF LAKELAND FINE SAND AND RELATED SOILS UNDER CITRUS PRODUCTION.

Soil Depth	Number of Nematodes
0-5″	21
5-10″	17
10-20″	12
20-30″	2
3-4′	0
4-6′	1
6-8′	0
8-10′	0

did not proceed at the same rate in samples from all horizons of the soil. This decrease occurred in spite of the fact that some nitrifiers could be found at all depths in the profile.

SUMMARY

A microbiological characterization of the soil profile of Lakeland fine sand and related soils under the canopy of citrus trees was made. Significant findings were as follows:

1. Sixty-seven 0- to 5-inch samples showed an average total production of 211 ppm of nitrate nitrogen in 28 days; sixty-four percent of the soils produced more than 200 ppm. Ninety-three percent of the soils had a pH higher than 5.5. These surface samples were taken from spreading decline areas in contrast to areas showing no decline symptoms, under grapefruit and orange trees and from the drip-line and row-middles. None of these variables affected nitrate production.

2. Profile studies, to a depth of ten feet, showed the following results:

a. Nitrate production was largely a function of the surface soil, but was appreciable to a depth of four feet after which the rate was less than four percent of the surface soil rate. Unlimed surface soils produced only 48 percent as much nitrate as when limed. Unlimed 5- to 10-inch and 10- to 20-inch zones produced negligible nitrate, these same horizons when limed produced 71 and 45 percent as much as the limed surface soil, respectively. Based on this study, it appears that nitrate production under surface liming procedures is, for the most part, a function of the surface five inches of soil, but could be of considerable consequence to a depth of thirty inches with deep applications of lime.

b. The range in apparent numbers of nitrifiers was 100,000 to 1,000,000, or more, per gram of soil in the 0- to 5-inch depth. Each successive depth through the 3- to 4-foot horizon resulted in a decrease of one-tenth in numbers. Below 4 feet there were 100 or less nitrifiers per gram of soil.

c. Nematodes decreased from an average of 21 per 150 cc of moist soil in the surface layer to essentially none below 30 inches.

d. An average of 42.6 thousand fungi and 3.17 million bacteria per gram were present in the surface five-inches of soil; they progressively decreased to approximately 15 percent of the surface quantity in the 8- to 10-foot horizon. Percentage-wise, bacteria were present in larger numbers to a depth of 6 feet than were the fungi.

It appears that certain of the soil microbes, like citrus roots, are able to carry on their life processes to a limited degree at depths of at least ten feet in the deep, well-drained sands of the citrus area.

ACKNOWLEDGMENT

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LITERATURE CITED

1. Allen, O. N. Experiments in Soil Bacteriology. Burgess Publishing Co. Minneapolis 15, Minn. 126 pp. 1949.
2. Blue, W. G., Eno, C. F. and Westgate, P. J. Influence of soil profile characteristics and nutrient concentrations on fungi and bacteria in Leon fine sand. Soil Sci. 80:303-308. 1955.
3. Brown, P. E. Bacteria at different depths in some typical Iowa soils. Iowa Agr. Exp. Sta. Res. Bul. 8, 1912.
4. Brown, P. E. and Benton, T. H. Microbiological studies of some typical Iowa profiles. Iowa Agr. Exp. Sta. Res. Bul. 132, 1930.
5. Christie, J. R. and Perry, V. G. Removing nematodes from soils. Proc. Helminthological Soc. Wash. 18 (2): 106. 1951.
6. Ford, H. W. The distribution of feeder roots of orange and grapefruit trees on rough lemon rootstock. Citrus magazine 14 (11): 22-23. 1952.
7. Ford, H. W. The influence of rootstock and tree age on root distribution of citrus. Proc. Amer. Soc. Hort. Sci. 63: 137-142. 1954.
8. Gammon, N. Jr., Henderson, J. R., Carrigan, R. A., Caldwell, R. E., Leighty, R. G., and Smith, F. B. Physical, spectrographic and chemical analyses of some virgin Florida soil. Fla. Agr. Exp. Sta. Tech. Bul. 524. 1953.
9. Gray, P. H. H. and McMaster, N. B. A microbiological study of podsol soil profiles. Can. J. Res. 8: 375-389. 1933.
10. Harper, H. J. The accurate determination of nitrate in soil. Jour. Ind. Eng. Chem. 16: 180. 1924.
11. Quastel, J. H. and Scholefield, P. G. Biochemistry of nitrification. Bact. Reviews 15: 1-53. 1951.
12. Smith F. B. and Gall, O. E. Types and distribution of microorganisms in some Florida soils. Fla. Agr. Exp. Sta. Bul. 396. 1944.
13. Stewart, R. and Greaves, J. E. A study of the production and movement of nitric nitrogen in an irrigated soil. Utah Agr. Exp. Sta. Bul. 106. 1909.
14. Timonin, M. T. Profile distribution of soil microflora. Can. J. Res. C 13: 32. 1935.
15. Waksman, S. A. Bacterial numbers in soils at different depths and in different seasons of the year. Soil Sci. 1: 363. 1916.
16. Waksman, S. A. Principles of Soil Microbiology. The Williams and Wilkins Co. Baltimore. 1927.
17. Waksman, S. A. Soil Microbiology. John Wiley and Sons, Inc., New York. 1952.

Mechanical Dewatering as a Potential Means for Improving the Supply of Quality Animal Feeds in the Tropics and Sub-Tropics[1]

J. W. Randolph, L. Rivera-Brenes, J. P. Winfree and V. E. Green, Jr.[2]

The need for concentrated livestock feeds in tropical and subtropical countries is illustrated by the facts that a) the average child living in equatorial regions receives less than one-tenth pint of milk per day, and b) most of the animal products consumed in these regions are imported canned items. There is no need to review the ills of an agricultural economy dependent largely upon a one-cash-crop system, or how in some Latin American regions a sugar economy has gained control over broad fertile valleys while the common folks, living in eroded hills and mountains, make their daily bread by working in the distant cane fields.

It is not the object here to indict this sugar economy, but it is rather to point out mans' submissiveness in the past to the natural factors that have paramount importance in areas of high rainfall, and to suggest an opportunity for agriculture to adapt "know-how" and equipment with which industry has already solved parallel problems (3) (8).

The interested reader is referred to a recently published description of the distribution, and insidious and horrible effects of protein deficiency diseases in man throughout the world (5). Perhaps the etiology of such diseases as "kwashiorkor" brings into sharpest focus the necessity for cattle and their products to mankind. To quote Spencer, "Of the many ways to fight malnutrition (in the tropics), one of the most effective is with milk" (5). In view of recent developments in preventive medicine and in agricultural research, there appears to be need for a re-appraisal of the type of counter-disease measures that may be employed in humanitarian programs.

The universally increasing desire for greater efficiency in the use of manpower and land gives logic to the following proposal. Technological automation can go a long way, but the health and wellbeing of many a nation's people depend in a large part upon the cow. If provided with low cost, complete feeds throughout the year, cattle can, in time, bring about changes among underfed people. The cane-sugar producing areas within the tropics and sub-tropics would appear to be logical places in which to pioneer a cattle feed production program, since these areas are concerned with a crop that has no equal in the annual per acre production of digestible nutrients.

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Restrictions within world sugar markets and especially within the dollar-areas should influence a varied utilization of land and encourage the acceptance of ways and means for profitable utilization of excess sugarcane and sugarcane wastes. It has been estimated that Puerto Rico's losses in sugarcane tops, figured on a dry basis, may represent 2,000,000 tons, 4 to 6 percent protein, roughage cattle feed (1). Cane tops can be readily fortified with blackstrap molasses and other local supplements to produce an adequate cow feed.

In spite of the crucial need for quality feeds in tropical and subtropical regions the preservation of many crops remains in many ways impractical. Two of the primary reasons for the failure to preserve and "feed out" forages economically are, a) forage crops in top quality condition contain "just-too-much-water" and, b) natural conditions, characteristically "wet," are generally unfavorable. Livestock production enterprises in southern Florida and southern Louisiana for years have been handicapped by the same two factors.

This applies particularly to the curing of hay. Rivera-Brenes in a review of problems encountered in Puerto Rico states: "Hay-making by allowing the grass to dry on the field is impossible in practice because of the frequency of showers in the rainy season and the very low yields from scanty rainfall in the dry season. It is in the rainy season that grasses are in best condition for hay-making" (4). Myers, *et al* (2) reached the same conclusion for Florida.

The two problems, a) "too much water" and b) unfavorable natural drying conditions seem to be of paramount importance in Puerto Rico's critical need for homegrown livestock feeds. Koenig has outlined the existing status and the potential in agricultural production. (1) The large deficiencies in livestock production enterprises in Puerto Rico, shown in Table 1, overshadow in value even millions of dollars spent annually by dairy farmers along Florida's "Gold Coast" for imported (out-of-state) feeds.

BASIC INFORMATION

It follows, then, that production of feeds in tropical and subtropical regions takes on special aspects in the modification of the original crop. Accordingly, excessive moisture may be a limiting factor not only in hay making but also in (a) direct feeding, (b) silage making, and (c) production of dry feeds. Whereas natural conditions unfavorable for crop preservation cannot be changed at will, fortunately the basic problem, "just-too-much-water," represents factors over which man may gain some control. While custom dictates that crop moisture data must be obtained from a sample collected in the midpart of a clear day, it is quite evident that such samples do not reflect the entire feeding habits of cattle as they must graze rain or shine at different times of the day. Figure 1 shows the ratio of water to solids in St. Augustinegrass during part of one day, representative of many in the Everglades. Much grazing occurs when moisture content is highest. Data collected during a day in the rainy season would be even more striking. Even in April, it is shown that at 7 A.M. a cow may have to ingest about 7.5 pounds of grass to obtain one pound of dry matter.

TABLE 1.—VALUE OF IMPORTED FOODSTUFFS, FODDER, AND FEEDS IN 1950-51, AND OVERALL DEFICIT FOR ANNUAL REQUIREMENT FOR A LOW COST ADEQUATE DIET IN PUERTO RICO (From Koenig, 1953).

	Total imports (dollars)	Deficit for annual low cost adequate diet. (pounds)
Meat and meat products	$15,945,000	6,470,000
Fat and oils, animal	9,405,000	
Other animal products	103,000	
Milk and milk products	14,770,000	472,100,000
Eggs and dried eggs	2,711,000	10,913,000
Grains and preparations	36,096,000	
Mixed dairy and poultry feeds	5,086,000	
Misc. crops, source of feeds	1,178,000	
Starchy vegetables and fruits	19,230,000	162,247,000
TOTAL	$104,524,000	651,730,000

THE APPLICATION OF MECHANICAL DEWATERING

One approach toward combating the high moisture problem has been through mechanical dewatering. Studies at the Everglades Experiment Station indicate that an industrial dewatering screw press of the type used in the citrus by-product industry can extract significant amounts of moisture from pasture, vegetable and field crops. The data in Fig. 3 were obtained in the Florida studies. They are expressed as the percentage increase in dry matter percentage as represented in the dewatered crop material (press-cake). The relative changes in dry matter content are expressed as a function of original moisture by the curvilinear regression shown. The green-chop forage

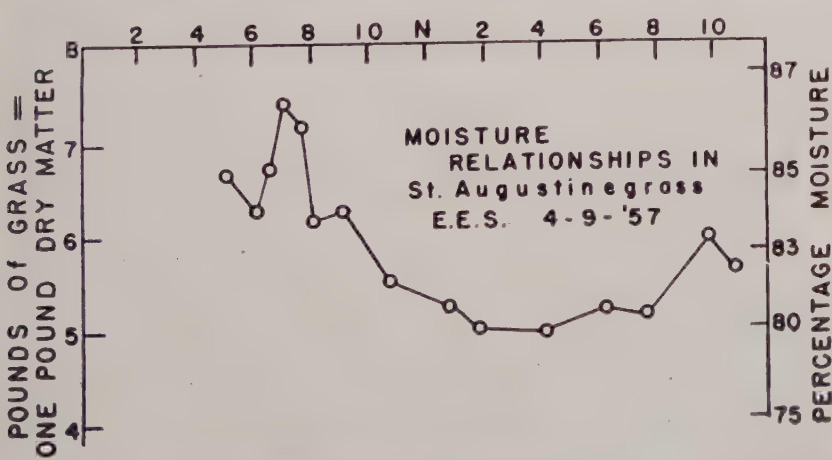

Figure 1.—Percentage water versus percentage solids in St. Augustinegrass as affected by time of day.

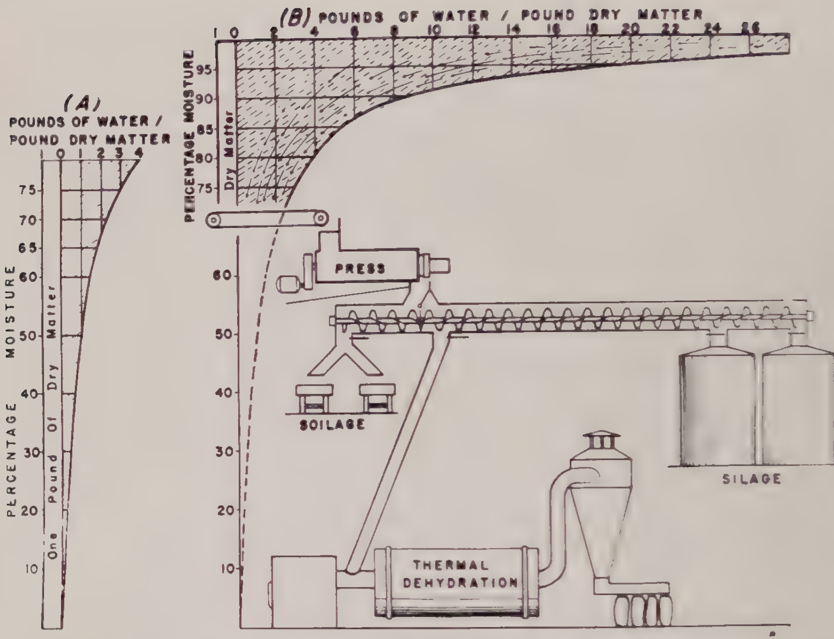

Figure 2.—The relationship between pounds of water per pound of dry matter and percentage moisture. (A) between zero and 80 percent and (B) between zero and 100 percent. The "B" part of the figure shows the application of mechanical dewatering to the production of soilage, silage and dehydrated feeds in tropical and subtropical areas.

materials represented the normal output of a forage crop harvester and no chemicals were added.

The moisture contents of a few Everglades grown crops are given in Figure 4 which shows the relationship between moisture percentage and the amount of water per unit of dry matter. As may be seen, this relationship is an exponential one. The shaded area of each block indicates the ratio water: dry matter in the press-cake, and the clear area indicates the difference in the water dilution of dry matter between fresh chops and press cakes.

In Figure 5, Line F-2 shows the relationship between the water remaining in the press cakes after they have been prepared from materials having percentages of moisture indicated along '.C.'. Line PR represents data from tests of crop materials that may be obtained in Puerto Rico. These consisted of Paragrass, Caribgrass, Napiergrass, green oats and white turnip tops. The right hand axis of Figure 5 shows the fuel oil requirements for thermal dehydration as they are related to the ratio of moisture to dry matter. Since curve line 'C.C.' is an expression of the true mathematical relationship between original moisture percentage and the ratio moisture: dry matter, the vertical interval between this curve line (C.C) and PR or F-2, gives theoretical indication of the potential improvement in many economies associated with soilage, silage making, and thermal dehydration.

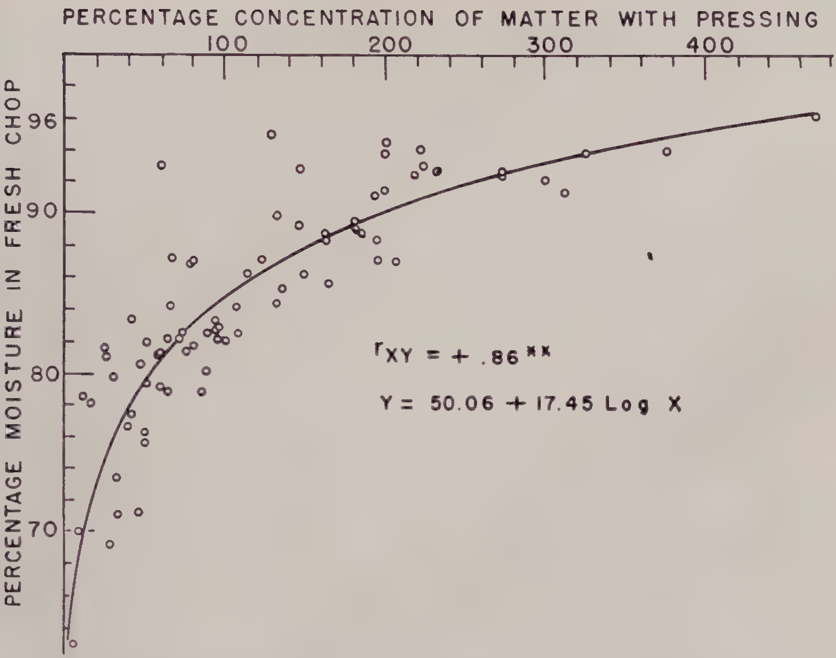

Figure 3.—The percentage concentration of dry matter of forage crops through mechanical dewatering as influenced by original (fresh chop) moisture content.

The relationship between moisture percentage and dilution of dry matter is shown in Figure 2 in two parts. That phase below 80 percent, which occurs in agricultural areas having favorable conditions for crop preservation, is represented in (A). The same part of the curve line (0-80 percent) is shown in the (B) section as a broken line. Mechanical dewatering has been injected diagramatically as the means of rendering higher moisture forages, those above 80 percent, more suitable for soilage, silage and thermal dehydration.

The differences in moisture content of Napiergrass taken from Everglades Station plots at different times of day and either pressed or left untreated, assume very practical significance when expressed in terms of dehydration requirements or the relative amount and uniformity of dry matter that may be consumed by a cow (Table 2).

The introduction of mechanical dewatering into the manufacture of concentrated feeds is accompanied by some chemical losses in the press liquors (3,6). Salvage of "losses" in the expelled plant juice has in part been answered by equipment and methods now in industrial use. Studies in England (7) and Italy (6) give indication that the solids, a fractional part of a forage press liquor, can be salvaged with economy by a chemical-mechanical extraction process that is comparable to making milk 'cottage-cheese.' "Grass-cheese" or "coagulate" will receive special consideration, since it is possible that some undesirable (to the animal) substances are removed in the soluble portions of the press liquors. The "grass-cheese" fractions as obtained in

TABLE 2.—The Moisture Content of Freshly Harvested and Mechanically Dewatered Napiergrass in Morning and Afternoon as it May Be Related to Thermal Dehydration Requirements and to Dry Matter Consumed by an Animal.

	Time of harvesting	
	Morning	Afternoon
Percentage of moisture in grass at time of harvest	87.0	71.5
Percentage of moisture in pressed grass	59.8	58.0
Pounds of water that must be evaporated to produce one ton of feed with 10 percent of moisture		
(a) original grass	12,000	4,370
(b) pressed grass	2,510	2,330
Pounds of dry matter consumed on basis of feeding 50 pounds of material as:		
(a) original grass	6.5	14.2
(b) pressed grass	20.1	21.0

the Florida investigations by chemical analysis verified literature citations that the extracts were low in fiber and high in certain qualities desired for supplemental feeds.

The final cost of the needed feeds cannot yet be predicted from the available data, but the potential fuel economies are evident from data presented here. It is to be recognized that in the case of dry meals heat costs for dehydration may be a major item of expense. If the sugar centrals in Latin-America could be the feed makers, consideration should be given to the possible salvage as usable heat for the excess "bagasse" which at present is burned in big waste piles.

This review of new techniques so far has overlooked the fact that certain new units of harvesting equipment are needed. Based upon experience in the Everglades, it is evident that no existing forage-field-crop-harvester has the capacity and service qualities needed in tropical growths of Merker-, Guinea-, and Napiergrasses and in recumbent sugarcane. Perhaps the machine that would be of great value under tropical conditions would be a forage-crop harvester of adequate proportions and construction with a mechanical dewatering attachment suitable for harvesting and dewatering a pasture grass thus making possible a kind of rotational "grazing" without need for additional fencing. Or press cake could be delivered via wagons or trucks to points of utilization in feed-lot soilage (direct feeding), silage making, and/or thermal dehydration.

Quality silage can be made from high-moisture forage materials after moderate dewatering (with the accompanying mechanical mastication) without the use of additives or preservatives. Much more dewatered forage can be put into a silo than can fresh chopped forage. This is advantageous both from the standpoint of space economy and for tight packing to prevent spoilage (Table 3).

Even small, primitive, and isolated farm and feeding enterprises may well be served by the application of the dewatering principle in an easily portable unit, such as is now in use in rural Italy (6), to existing methods of forage feed harvesting, preservation, and utiliza-

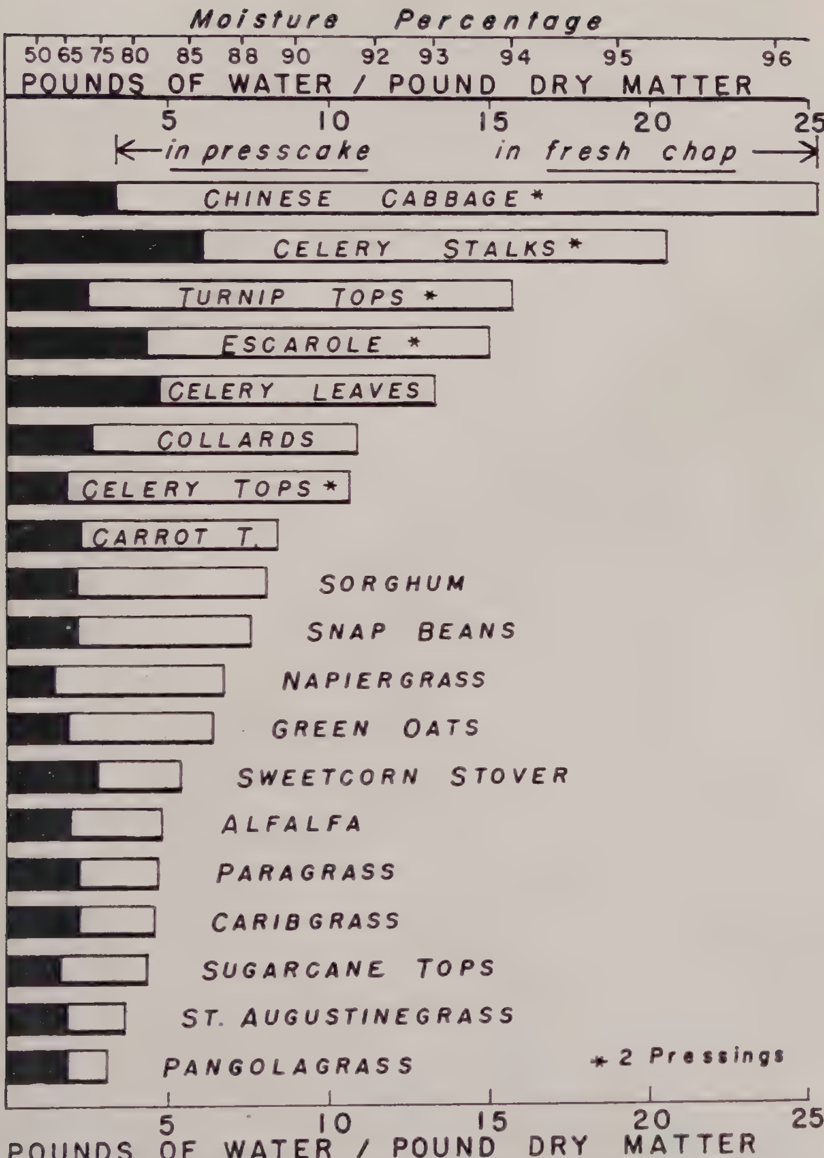

Figure 4.—Amount of water per pound of dry matter contained in several forage and potential forage crops as harvested (fresh chop) and following mechanical dewatering. The upper (wetter) portion is occupied by succulent, winter-grown vegetables and their waste products; the lower (drier) portion by the less succulent pasture and field crops.

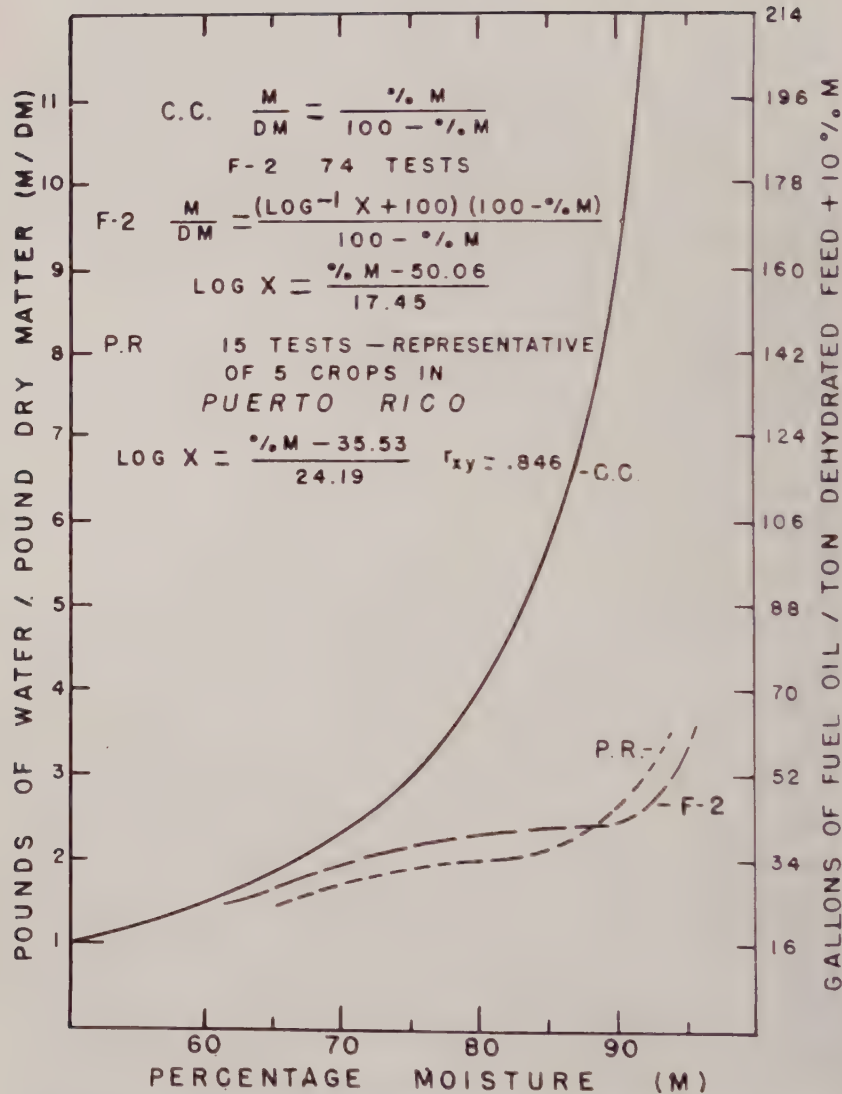

Figure 5.—The relationship between percentage moisture and pounds of water per pound of dry matter. The right axis shows the fuel oil requirements for thermal dehydration as related to the ratio of moisture to dry matter. Curve "C" is the true mathematical relation between original moisture and the ratio of moisture to dry matter. The vertical interval between curve "C" and PR or F-2 gives an exact indication of the concentration of dry matter effected in mechanical dewatering.

TABLE 3.—DENSITY AND pH OF SILAGE AS INFLUENCED BY MECHANICAL DEWATERING.

Crop Material	Fresh chop			Press Cake		
	Percentage Moisture	Dry matter Per Cu. ft. (lbs.)	pH[1]	Percentage Moisture	Dry matter Per Cu. ft.	pH[1]
Turnip tops	93.9	3.6	4.4	74.0	18.1	4.1
Napiergrass	87.0	5.9	4.9	59.8	21.8	3.9
Pangolagrass	82.1	8.1	4.3	72.6	15.4	3.9
Paragrass	82.2	5.8	4.8	75.9	9.9	4.2
Caribgrass	80.6	7.0	4.8	73.3	13.6	4.0
St. Augustine grass	78.1	8.4	5.0	74.6	11.9	4.3

[1]Reaction values attained after two weeks or more. A pH of 4.2 or below is desirable.

tion. In fact, the greatest potential value of such a system may lie in its application within the less developed areas which lack resources other than fertile soil and abundant rainfall, and are dependent upon an agrarian economy for survival but are ill-equipped to progress simply because they cannot adequately feed their cattle, themselves and their children.

LITERATURE CITED

1. Koenig, Nathan. 1953. A Comprehensive Agricultural Program for Puerto Rico. U. S. Dept. of Agric. in cooperation with the Commonwealth of Puerto Rico, unnumbered publication.
2. Myers, J. M., G. B. Killinger and R. W. Bledsoe. 1948. Methods of Curing Florida Hays. Fla. Agr. Expt. Sta. Ann. Rept. 1948; 38.
3. Randolph, J. W., J. P. Winfree and V. E. Green, Jr. Mechanical Dewatering of Forage Crops. Everglades Expt. Sta. Mimeo Rept. 58-14. April 25, 1958, Belle Glade, Fla.
4. Riviera-Brenes, R. 1953. Technical and Economic Aspects of Roughage Production in Puerto Rico, Agric. Expt. Sta., Univ. of P.R. Tech. Paper 12.
5. Spencer, Stephen. 1957. The Secret Killer of Children. Sat. Eve. Post 230 (7): 28.
6. Tallarico, G., and B. Fagotti. 1957. La Conservazione del foraggi freshi. Litostampa. Via Brescia 19, Rome, Italy.
7. Raymond, W. F. and J.M.A. Tilley. 1956. The Extraction of Protein Concentrates from Leaves. Colonial Plant and Animal Products 6 (1): 3-19. London.
8. Randolph, J. W., D. B. Vincent and R. V. Allison. Preliminary Studies of Mechanical Dewatering as an Aid to Dehydration of Florida Forages. Soil & Crop Sci. Soc. of Fla. Proc. XVI: 321-333, 1956.

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Photosynthetic and Soil Respiration Measurements with Various Crops

VINCENT N. SCHRODER*

Scientists have long been interested in photosynthesis and respiration, and these processes are generally studied by measuring the amount of carbon dioxide taken up or released. Many of the problems are not new. The approaches and techniques used to study these problems, however, do change and improve and enable us to take a new look at some of these things.

One of the common ways of measuring carbon dioxide gas is to absorb the gas in a standardized solution of sodium or potassium hydroxide and then titrate with an acid of known strength, or to measure the hydroxide for changes in electrical conductivity before and after the gas has been absorbed. A method that has come into more common use during the last few years, in both research and industry, is that of the infrared gas analyzer. Although both the principle of the analyzer and the history of its development have been described in the literature (5), a brief description will be included here.

This method is based upon the fact that carbon dioxide is a very powerful absorber of infrared radiation. The analyzer unit contains two identical infrared energy sources, a motor-driven 10 cycle per second energy beam chopper, a sample tube, a reference tube, and a detector divided into two chambers by a diaphragm-condenser. The detector is sensitized by filling both chambers to the same pressure with the type of gas the instrument is to detect and measure, in this case carbon dioxide. Infrared energy from one source passes through the sample tube and from the other source through the reference tube. These tubes have windows of quartz or other material permeable to infrared radiation. When the infrared energy falls on the detector, this energy will be absorbed only in regions where the sensitizing gas has absorption bands, resulting in a highly selective detector. The energy absorbed by the gas in the detector causes this gas to expand and exert pressure against the sensitive diaphragm. This diaphragm forms one plate of a condenser, the other plate of the condenser being a stationary electrode. Radio frequency voltages are applied across this condenser and a very small movement of the diaphragm will produce a frequency change which may be detected, amplified and employed to drive a recorder or produce a direct reading on a meter. The aforementioned energy beam chopper causes an intermittant interruption of the beams of infrared energy resulting in pulsations of energy reaching the detector. This is necessary to prevent a continuous temperature rise and increased pressure in the detector which would result if the energy beam was not interrupted.

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In actual use the gas mixture to be analyzed is introduced into the sample tube. If the amount of carbon dioxide in the sample tube is the same as the amount in the reference tube, the infrared energy pulsations passing through each tube and reaching each chamber of the detector will be equal. If the gas mixture in the sample tube contains more carbon dioxide than that in the reference cell, the amount of energy transmitted to the sample detector will be decreased. If the gas mixture contains less carbon dioxide, more energy will reach the detector. Thus it can be seen that any change in carbon dioxide content will affect the amount of energy passing through the sample tube, and this change of energy, which can be measured, is proportional to the carbon dioxide concentration.

Infrared analysis can be used for other heteroatomic gases also, such as carbon monoxide and methane, but is not adaptable for gases such as nitrogen and oxygen. The principle of the analyzer is quite simple, but the electronics are complicated. The response of the analyzer is almost instantaneous and it can be used for continuous determinations.

Calibration of the instrument was accomplished by using a closed system of approximately 20 liters. The air was moved through this system and through the gas analyzer by means of a diaphragm pump. First, all the carbon dioxide was removed by chemical means. Then known amounts were injected into the system. The response of the gas analyzer is essentially linear from 1 part to 5 parts of carbon dioxide in 10,000 parts of air making it very easy to work in this range. Since normal air concentration of carbon dioxide is 3 parts in 10,000 this range adequately covers the conditions generally found in the field. By adjusting the sensitivity this instrument can be used for measurements over a much wider range.

That changes in the carbon dioxide concentration affect photosynthesis has been reported by a number of authors (2, 4, 8). Even minor changes in the CO_2 concentration are important. Work by the author using tobacco plants has shown that when the average carbon dioxide content was maintained at 10 percent above normal the photosynthetic rate was 9 percent higher than at normal concentrations and 21 percent higher than when the carbon dioxide was maintained at 10 percent below normal. This 21 percent increase in photosynthesis resulted from a change of only 6 parts per 100,000 of carbon dioxide in the air. These results were obtained under conditions where other factors such as light, temperature and moisture were not limiting.

Plants use large amounts of carbon dioxide when growing rapidly. Brougham (3) reported that in a ryegrass-clover pasture daily increments in total herbage approached 150 pounds of dry matter per acre. Most of this increase comes from the carbon dioxide of the air. Miller (4) has pointed out the large quantities used by corn. Bonner and Galston (2) have stated that the carbon dioxide content of the air in a corn field may drop to one-third of normal on windless days. It appeared to be a simple matter to go out into some corn fields and measure these changes if they occurred, but so far it has not been possible to demonstrate any depletion of the carbon dioxide

TABLE I.—Carbon Dioxide Evolution From Soil.

	Grams CO_2 evolved per square meter per day	Source
Bare ground	1.6- 4.8	Russell (6)
Rye	5.4-10.2	Russell (6)
Potatoes	11.8-12.7	Russell (6)
Lundegardh	2.6-50.	Russell (6)
Sjöstrom	13.7	Baver (1)
Orchardgrass	211.2	Wallis & Wilde (9)

supply with corn or other crops even under ideal growing conditions.

Soil respiration measurements were made to see if the amount of carbon dioxide evolved from the soil was sufficient to supply the needs of the plants. In Table I are given some figures from a number of workers showing carbon dioxide evolution for various crops. In some cases the figures had to be converted to the common basis used in the table. The conditions of temperature and soil moisture under which the results were obtained are not given. The figure for orchardgrass appears to be too high to be reliable. On an acre basis it would amount to almost 1900 pounds of carbon dioxide evolved per day, an amount many times higher than any reported elsewhere in the literature or found in this study. This high value is probably due to their method of applying suction to the soil to remove the carbon dioxide.

The measured rates of respiration have varied with the type of plant growing on the soil and with the time of the year. Measurements for bare ground in the Gainesville area have ranged from 7.7 to 12.2 grams of carbon dioxide evolved per square meter per day during the month of August to 3.4 grams during the month of November. Data for carbon dioxide evolution from various sods are presented in Table II. From these data it can be seen that respiration decreases as the season progresses. The August and September measurements were made at temperatures of 97° to 100° F while the November measurements were made at a temperature of 76° F. However, it must not be assumed that temperature is the only factor involved. According to Waksman (7) soil microorganisms are responsible for most of the carbon dioxide evolved from the soil, but temperature, moisture, oxygen, and the growing crop have direct and indirect effects. Baver (1) discusses in some detail the effects of various soil characteristics on carbon dioxide evolution. It is apparent that the two inch stubble of Bahiagrass gave off more carbon dioxide than bare soil, but less than the eight inch growth of the grass. The present data are not sufficient to lead to any conclusions involving interactions of the various factors affecting carbon dioxide evolution.

Photosynthetic measurements were made on the same areas where the respiration measurements were made, and these results were presented in Table III. In the process of photosynthesis carbon dioxide is removed from the air and fixed by the plant, and since this process occurs only in the light, the rates have been expressed on an hourly rather than a daily basis. An approximation of the daily rate can be obtained by multiplying the hourly rate by the number of hours of sunlight per day. If, for example, we multiply the highest rate for

TABLE 2.—Respiration Measurements of Pensacola Bahiagrass and Coastal Bermudagrass in the Field.

		Date	Grams CO_2 evolved per square meter per day	per hour
P. Bahia	2″ stubble	8-26-58	21.6	0.90
P. Bahia	8″ sod	8-26-58	36.2	1.51
C. Bermuda	8″ sod	9-26-58	26.7	1.11
P. Bahia	8″ sod	8-26-58	36.2	1.51
P. Bahia	6″ sod	11-7-58	11.2	0.47
C. Bermuda	8″ sod	11-7-58	12.0	0.50

TABLE 3.—Photosynthetic Measurements of Pensacola Bahiagrass and Coastal Bermudagrass in the Field.

		Date	Grams CO_2 absorbed per square meter per hour
P. Bahia	2″ stubble	8-26-58	0.00
P. Bahia	8″ sod	8-26-58	2.04
C. Bermuda	8″ sod	9-26-58	2.04
P. Bahia	8″ sod	8-26-58	2.90
P. Bahia	6″ sod	11-7-58	0.60
C. Bermuda	8″ sod	11-7-58	0.90

Bahiagrass by 8, we would obtain a figure of approximately 23 grams of carbon dioxide fixed per square meter per 8 hour day. This is equivalent to 207 pounds of carbon dioxide fixed per acre in 8 hours which is an excellent increase for almost any crop. Photosynthesis is dependent upon a number of factors which vary greatly under field conditions so care must be used when making comparisons or drawing conclusions.

It is apparent from the data on respiration and photosynthesis that the amount of carbon dioxide evolved from the soil was sufficient to supply at least one-half the amount used by the plants. When maximum photosynthesis was occurring large amounts of carbon dioxide were removed from the air without measurable changing the carbon dioxide concentration of the air surrounding the plants. From the measurements to date it is not apparent whether carbon dioxide evolution from the soil in immediate vicinity of the plants is necessary for maximum plant growth or whether normal air movement and diffusion can at all times supply sufficient carbon dioxide from the atmosphere.

LITERATURE CITED

1. Baver, L. D. 1956. Soil Physics. John Wiley & Sons, Inc., New York.
2. Bonner, J., and A. W. Galston 1952. Principles of Plant Physiology. W. H. Freeman & Co., San Francisco.
3. Brougham, R. W. 1955. A study in the rate of pasture growth. Australian Jour. of Ag. Res. 6:804-812.

4. Miller, E. C. 1938. Plant Physiology. McGraw-Hill Book Co., Inc., New York.
5. Parker, J. 1953. Criteria of life. Amer. Scientist 41:614-618.
6. Russell, E. J. 1932. Soil Conditions and Plant Growth. Longmans, Green and Co., London.
7. Waksman, S. A. 1952. Soil Microbiology. John Wiley & Sons, Inc., New York.
8. Waksman, S. A. and R. L. Starkey. 1931. The Soil and the Microbe. John Wiley and sons, Inc., New York.
9. Wallis, G. W. and S. A. Wilde. 1957. Rapid method for the determination of carbon dioxide evolved from forest soils. Ecology 38:359-361.

Soil Phosphorus Reserves in Old Vegetable Fields In the Sanford Area

P. J. Westgate, R. B. Forbes and W. G. Blue*

The retention of phosphorus by soils has been known for over a century as shown by Way (10) in 1850. Bryan (3) found an accumulation of as much as 60,000 pounds of 16% superphosphate, equivalent to 9,600 pounds of P_2O_5, per acre foot in old citrus soils in Florida. Total available and water soluble forms of phosphorus increased with the age of citrus groves, and no plant response resulted from added phosphates on these soils. Incidentally, Bryan (3) showed more water soluble phosphorus extracted from a 20 year old Sanford celery field (Leon fine sand) than from any citrus soil.

Reuther et al (8) reported no beneficial response in tree growth, yield, or fruit quality of citrus from the application of phosphate over a period of six years. Smith (9) found these conclusions in regard to added phosphates to hold true after thirteen years, with the added observation that the total weight of citrus feeder roots in the top sixty inches of soil was nearly one third less in high phosphate plots than in the plots where no phosphate was applied.

Forbes (5) found a build-up of phosphates, both total and available, in fertilized pastures on soils similar to those used for vegetable production in the Sanford area.

Westgate et al (11) reported up to 10,000 pounds per acre (0-6") of P_2O_5 in an old Sanford celery farm which had been cropped for over fifty years.

Forsee (6) determined that a 0-6" soil sample from an old commercial celery field near Sanford contained 135 pounds per acre of *water soluble* phosphorus (P). Ten pounds of *water soluble* P is considered (6) ample for maximum crop growth.

Chase (4) has pointed out that Sanford was primarily a citrus area before the 1895 freeze. The first four carloads of celery were shipped from Sanford in 1899. Thus the older vegetable fields in this area have been farmed for half a century. At present there are 6,000 acres planted to vegetables in Seminole County, of which Sanford is the county seat.

The purpose of this paper is to report the magnitude of the phosphorus reserves built up in old vegetable fields of the Sanford area, and the availability of this phosphorus for crop production.

METHODS AND RESULTS

In the spring of 1954, twenty four plots 1/100 acres in size were laid out at the Station farm on fine sand. This farm had been under cultivation for approximately fifty years. The plots were fertilized

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with six levels of phosphate, namely 0, 50, 100, 150, 200, and 500 pounds of P_2O_5 per acre in the form of super-phosphate (18% P_2O_5). Each phosphate level was replicated four times. All plots received nitrate of potash at the rate of 900 pounds per acre and MgO at the rate of 15 pounds per acre. There was no significant difference (19:1) in sweet corn yields for any of the phosphate treatments in comparison to the checks which received no added phosphate. The yields on all plots were comparable to average yields of sweet corn grown on commercial fields in the area.

In January 1956, composite soil samples (0-6") were collected from twenty selected vegetable farms in the Sanford area along with information as to the number of years these various farms had been cropped. These soil samples were analyzed for total phosphorus (P_2O_5), and the results plotted against the number of years of cropping, as shown in Figure 1. Blue et al (1) have reported the linear equation for this relationship between years of cropping and soil phosphorus to be $Y = 149.8\ X + 530.8$ with a significant coefficient of correlation (r) of 0.880. Thus there is a positive correlation between the number of years of cropping and the total phosphorus in the soil.

In the fall of 1954, sixteen permanent plots, 1/100 acre each, were set up on fine sand at the Central Florida Experiment Station farm. Eight plots, designated as the NPK plots, have been fertilized with a complete fertilizer, including nitrate of soda, potassium sulfate, and superphosphate. Eight additional plots, referred to as the NK plots, have been fertilized with nitrate of soda and potassium sulfate, omitting all phosphates from the fertilizer.

Pascal celery was the first experimental crop planted on these permanent NPK versus NK plots in the fall of 1954. There was no significant difference (19:1) in yield of celery between the plots receiving fertilizer containing phosphate, and those plots which received no phosphate.

The second crop grown on these permanent plots was sweet corn planted in the spring of 1955. There was no significant difference in yield of sweet corn from the plots receiving phosphate and those not receiving phosphate.

The third crop to be planted on these permanent plots was celery in the fall of 1955, when again there was no significant difference between yields of celery from NPK and NK plots. The average yield of celery from the experimental plots was 900 crates per acre, well above the 646 crate per acre average for Sanford that season.

The fourth crop planted on these same plots was celery in the fall of 1956. There was no significant difference in yields between the plots which had received phosphate and those which had not received phosphate.

Cabbage planted in the fall of 1957 was the fifth crop in four years to be planted on these same permanent plots, and again there was no significant difference between yields, even though the identical NK plots had received no phosphate for four years in comparison to the NPK plots which had received the usual amount of phosphate for each crop.

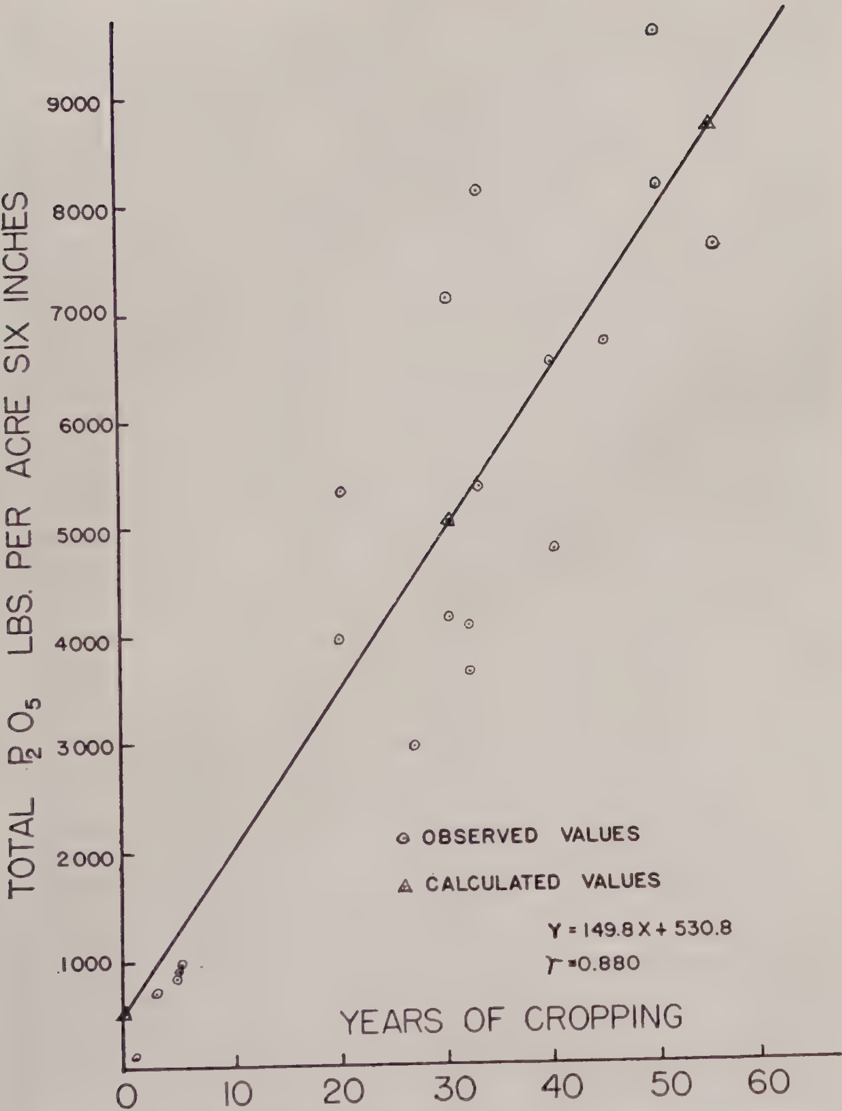

Figure 1. Total soil phosphorus (pounds P_2O_5 per acre) versus years cropped.

The celery crops on the NPK and NK plots were fertilized at the rate of three tons of 5-5-8 or 5-0-8 fertilizer per acre respectively, whereas the corn and cabbage were fertilized at the rate of one ton per acre with the same formulations. Borax at 10 pounds per acre per year and MgO at 2% of the weight of the fertilizer were used on all plots to supply boron and magnesium for maximum crop growth.

The omission of superphosphate from a complete fertilizer for these old vegetable fields high in total and available phosphorus

would also leave out a certain amount of the essential element sulfur which might in turn limit growth. In order to avoid this possibility, potassium sulfate was used as a source of potash and sulfur in the fertilizer for the NK and NPK plots.

In 1957 celery plots adjacent to the permanent NK vs. NPK plots were set up. These replicated plots with all sulfur omitted from the fertilizer showed no significant difference in yield when compared to plots receiving sulfur. This indicated that omitting the sulfur carried by superphosphate did not affect celery growth.

Superphosphate, in addition to furnishing phosphorus and sulfur, also supplies calcium. If calcium became limiting it could be added as gypsum, lime or dolomite.

Soil samples from all plots in the permanent NPK vs. NK experiment were analyzed from time to time for total phosphorus, available phosphorus,* and pH. A summary of these determinations of 0-6" soil samples is given in Table 1.

TABLE 1.—Available and Total Phosphorus (0-6" Soil Samples) in the Permanent NK and NPK Plots, Including pH. Data are Means of Eight Replicate Plots.

	Available Phosphorus				Total Phosphorus	pH
Plot Treatment	Sept. 1956 Lbs. P_2O_5/A	Dec. 1956 Lbs. P_2O_5/A	May 1957 Lbs. P_2O_5/A	Feb. 1958 Lbs. P_2O_5/A	Feb. 1958 Lbs. P_2O_5/A	Feb. 1958
NK	135	138	157	124	7000	7.00
NPK	151	163	315	222	7300	6.4

Thus after four years of experimental cropping, including three crops of celery, and one each of sweet corn and cabbage, there was still 7000 pounds of total phosphorus (P_2O_5) per acre six inches in the NK plots in comparison to 7300 pounds in the NPK plots in this 50 year old field. When phosphate is added to the soil, a certain percentage is taken up by the crop, some is leached below the surface six inches of soil, some is eroded by rain and wind, and the rest remains in the surface six inches of soil.

It is also of interest to note that after four years of experimental cropping the NK plots, with no phosphate added, still showed 124 pounds of available phosphorus (P_2O_5 acetate soluble) in comparison to 222 pounds in the NPK plots. In most soils anything over 25 or 30 pounds of available phosphorus (P_2O_5 acetate soluble) is considered high (2) (7). These NK plots, after four years of cropping without added phosphorus, probably have enough available phosphorus to last for several additional crop years.

*Extracted with Morgan's solution (sodium acetate at pH 4.8).

The available phosphate in this soil is only a small part of the 7000 pounds of total phosphorus (P_2O_5) in the top six inches of soil. This total phosphorus (P_2O_5) is equivalent to over 19 tons of 18% superphosphate per acre present in the top six inches of soil in some of these older vegetable fields in the Sanford area.

SUMMARY

A survey of vegetable farms in the Sanford area shows a positive correlation between the number of years of cropping and the total phosphorus in the top six inches of soil which amounts to as much as 10,000 pounds total P_2O_5 per acre in the older farms which have been cultivated for fifty years.

Celery, sweet corn, and cabbage over a period of four years on one of these older vegetable fields show no significant differences in yields between plots fertilized with additional phosphate, and those receiving no additional phosphate. Experimental plot yields were equal to or above average commercial yields for the area.

Soil analyses show an average of 124 pounds of available P_2O_5 (acetate soluble) per acre six inches still present in plots cropped for four years without additional phosphate, when 25 or 30 pounds of available phosphorus (acetate soluble P_2O_5) per acre are considered ample for maximum crop production.

LITERATURE CITED

1. Blue et al. State Proj. 328. Fla. Agr. Expt. Sta. Ann. Report, Soils Dept. p. 123. 1956.
2. Breland, H. L. Soil Test Report, Soil Testing Lab. Fla. Agr. Expt. Sta. Gainesville, Fla. 1957.
3. Bryan, O. C. The accumulation and availability of phosphorus in old citrus grove soils. Soil Sci. 36: 245-259. 1933.
4. Chase, R. C. Sketch of the early vegetable industry in the Sanford area. Proc. Soil and Crop Sci. Soc. Fla. 16: 11-15. 1956.
5. Forbes, R. B. The effects of fertilizers and pasture crops on Immokalee fine sand. M. S. in Agr. Thesis. Univ. of Fla., Gainesville. 1948.
6. Forsee, W. T. Jr. Everglades Expt. Sta., Belle Glade, Fla. Personal Communication, May 5, 1952.
7. National Soil Research Committee, North Carolina Agr. Expt. Sta. Tech. Bul. 121. p. 14. 1956.
8. Reuther, W., F. E. Gardner, P. F. Smith, and W. R. Roy. A progress report on phosphate fertilizer trials with oranges in Florida. Proc. Fla. State Hort. Soc. 61: 44-60. 1948.
9. Smith, Paul F. Effect of phosphate fertilization on root growth, soil pH, and chemical constituents at different depths in an acid sandy Florida citrus soil. Proc. Fla. State Hort. Soc. 69: 25-29. 1956.
10. Way, J. T. On the power of soils to absorb manures. Jour. Roy. Agr. Soc. 11: 313-379. 1850.
11. Westgate, P. J., W. G. Blue, and C. F. Eno. Blackheart of celery and its relationship to soil fertility and plant composition. Proc. Fla. State Hort. Soc. 67: 158-163. 1954.

Effects of Phosphate Additions on Acetate-Extractable Aluminum in Two West Florida Soils and on Corn Yields

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Aluminum as a component of the soil exchange complex and its role in fertilizer reactions in the soil have not been studied intensively. As early as 1923, information was published by several workers (1, 2, 4) which indicated that easily soluble aluminum was toxic to crops grown in acid soils and that organic matter, liming and phosphate were effective in improving plant growth on such soil. Phosphate fixation has also been generally found to be greatest in soils high in aluminum. Since clay minerals are continually in a process of weathering, the decomposition of the gibbsite-silica layers has furnished the most likely source of aluminum on the exchange complex. Some Florida sandy soils might also have received aluminum-bearing salts or colloids in salt and fresh flood waters.

The purpose of this investigation was to study the effect of phosphate fertilization on aluminum extractable with normal acid ammonium acetate at pH 4.8 and to determine the possible relationships with other elements and with corn yields.

ROW AND BROADCAST PHOSPHATE EFFECTS

Methods. The experiment was located on Faceville fine sandy loam at the West Florida Station. Three of the five replicates were on soil possibly transitional with adjacent Greenville fine sandy loam. Rates of phosphate in both row and broadcast applications were in increments of 45 pounds of P_2O_5 from 0 to 270 pounds per acre. The broadcast phosphate was spread before the final discing. The row phosphate treatments were applied at planting time. A uniform application of 60 pounds of N per acre was made at planting, 100 pounds of K_2O at the first plowing and 100 pounds of N at the second plowing. Dixie 18 corn was grown in 4-row plots 40 feet long with five replications. Corn yields were obtained from the center rows in the usual manner. The soil samples were taken in August after the corn was matured. Composites of twenty cores taken to a depth of six inches from the root zone of each plot were placed in polyethylene bags.

The damp samples were sieved before analysis. Dry weight was obtained at 70°C. The damp soil was spread out and sub-sampled at about 10 locations to obtain 25 grams for analysis. The soil was shaken for one hour with 200 ml. of 2N NH_4Ac, pH 4.8, and im-

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mediately filtered through Whatman No. 30 filter paper. Aluminum was determined on a 2 ml. aliquot by the method of Yuan and Fiskell (10). The Ca and K determinations were made using the Beckman DU flame photometer with hydrogen-oxygen fuel. An aliquot of 100 ml. of the acetate extract was evaporated to dryness. Organic residues were destroyed by concentrated nitric acid. The residue was dissolved in 50 ml. of normal H_2SO_4 and analyses for P, Mg, Mn and Fe were made by colorimetric methods previously described (6). The soil pH in water and in 1 N KCl was determined using the glass electrode. The cation exchange capacity was obtained by leaching the soil first with normal ammonium acetate at pH 4.8 or 7.0. This was followed by several leachings with neutral 4 N NH_4Cl to complete the NH_4-ion saturation and remove acetate and then several times with ethyl alcohol to remove soluble salt. The ammonium ion was displaced with 1 N HCl and determined by the usual distillation method.

Other extractions of 24 or more of the samples were made with 1 N NH_4Ac at pH 4.8 on dry soil, 1 N HCl and the 2 N NH_4Ac as above except that in the latter case contact of soil and solution was for a period of 72 hours. Aluminum and several other elements were determined in these leachates.

Extractable aluminum. The aluminum values extracted by acid 2 N NH_4Ac are shown in Table 1. The effect of phosphate rates in row application on aluminum was not significant at the 5 percent level although the 225 and 270 pounds of P_2O_5 showed a trend towards lower values. The sampling of the fertilizer band may not have been

TABLE 1. Effect of Row or Broadcast Phosphate Applications on Soil Aluminum in Faceville Fine Sandy Loam Extracted by Two Normal Acid (pH 4.8) Ammonium Acetate in One Hour of Shaking.
(parts per million, Al)

	Phosphate applied, pounds P_2O_5 per acre							
Replicates	0	45	90	135	180	225	270	Mean
				Row application[a]				
1	127	122	118	109	199	123	114	130
2	150	144	145	113	174	110	132	138
3	113	132	130	149	128	150	104	127
4	148	193	148	154	130	87	99	137
5	218	154	183	144	100	126	101	147
Average	151	149	145	134	146	119	110	136
				Broadcast application**				
1	136	123	232	127	141	145	124	149
2	168	168	172	170	123	126	98	146
3	226	194	130	130	158	144	131	159
4	190	164	189	149	126	194	116	161
5	228	224	167	127	128	158	130	166
Average	190	175	178	141	133	153	120	156

[a]Treatment means not significantly different for row application.
**L.S.D. between broadcast treatment means 38 at 5% level and 52 at 1% level.

made with the same efficiency from plot to plot which would, in effect, introduce varying amounts of non-phosphated soil with that in the band area. However, since the variability in the plots without phosphate is very great the sampling error can be discounted to some extend. Average values for row fertilization were not different than for the broadcast method. In the latter case, aluminum was decreased by phosphate applications with a probability of 99 out of 100. Actually only the 135, 180 and 270 pounds of P_2O_5 were significantly lower while the 225-pound rate with one high value was not. Sampling of broadcast treatments was likely to be more efficient in being truly representative of the soil. The averages for the replicates were alike statistically. However, the high variability within treatments may have occurred because this area was used in previous years for small experiments such as variety trials for cotton, grain sorghum and sweet corn. The previous phosphate additions may have had a residual effect which would not necessarily coincide with the present treatments. The fact that extractable aluminum is reduced by the phosphate additions, indicated that phosphate reaction is likely with aluminum on the exchange complex.

Aluminum data shown in Table 2 are much higher than in Table 1. However, in this case row application of P_2O_5 at 180, 225 and 270 pounds significantly reduced the aluminum extracted. With broadcast application the effect was less pronounced. Little is known about the effect of time on aluminum release by an extracting solution, however, the rapid extraction would be expected to release more of the exchangeable aluminum and induce less solubility or slow replacement of leached aluminum from other soil forms than for the 72 hours of contact.

Extraction with dilute HCl was made for 28 samples. In Table 3, the Al, Fe and P values are shown. These aluminum values were not decreased by either row or broadcast phosphate rates. Iron values likewise were not significantly different between treatments. However, the phosphate extracted was in direct proportion to the rate of phosphate applied. This was more pronounced for row application

TABLE 2. ALUMINUM EXTRACTED BY TWO NORMAL AMMONIUM ACETATE AFTER 72 HOURS STANDING FOLLOWING AN HOUR SHAKING OF FACEVILLE FINE SANDY LOAM TREATED WITH SEVERAL RATES OF PHOSPHATE APPLIED ROW OR BROADCAST.

Method P_2O_5 applied	Phosphate fertilization, pounds P_2O_5 per acre							
	0	45	90	135	180	225	270	Ave.
Row	384	322	345	298	209	255	201	287
Broadcast	341	310	258	262	248	272	228	274
Average	363	316	302	280	229	263	215	280
Difference (row-broadcast)	43	12	83	36	−39	−17	−27	

L.S.D. between rates of P_2O_5, 48 ppm. at 5% level and 63 ppm. at the 1% level. Row vs. broadcast method not significant.

TABLE 3. ALUMINUM, IRON AND PHOSPHORUS EXTRACTED BY NORMAL HYDROCHLORIC ACID FROM FACEVILLE FINE SANDY LOAM TREATED WITH VARIOUS PHOSPHATE RATES.

Method P_2O_5 Applied	Phosphate applied, pounds of P_2O_5 per acre						
	0	45	90	135	180	225	270
			Aluminum, ppm Al				
Row	1270	1020	1680	1700	1600	1480	1450
Broadcast	1200	1330	1250	1600	1480	1200	1070
			Iron, ppm Fe				
Row	850	860	940	950	970	760	940
Broadcast	880	850	1000	1050	980	800	790
			Phosphate, ppm P				
Row	50	61	82	105	170	310	340
Broadcast	51	46	54	65	70	77	113

TABLE 4. EFFECT OF RATES OF ROW OR BROADCAST PHOSPHATE APPLICATIONS ON CORN YIELDS GROWN ON FACEVILLE FINE SANDY LOAM AT THE WEST FLORIDA STATION. (bushels per acre)

Replicate Number	Method P_2O_5 Applied	Phosphate fertilization[a], pounds of P_2O_5 per acre							
		0	45	90	135	180	225	270	Ave
1	Row	78	80	83	83	60	67	81	76
1	Broadcast	90	82	66	69	75	76	72	76
2	Row	72	76	81	84	61	79	83	77
2	Broadcast	75	79	72	72	75	74	93	77
3	Row	86	84	60	59	77	79	82	75
3	Broadcast	79	76	75	68	65	94	89	78
4	Row	75	46	60	76	80	82	90	73
4	Broadcast	74	67	68	65	88	74	69	72
5	Row	55	68	81	66	75	84	89	74
5	Broadcast	72	74	70	89	68	74	85	76
	Average	76	73	72	73	72	78	83	75

[a]Fertility was 60 pounds of N at planting, 100 pounds of K_2O at first plowing and 100 lbs. of N at second plowing.

which indicates that these samples did in effect represent the higher concentration of phosphate in row than in broadcast treatments. Recovery of applied phosphate was not complete with dilute HCl.

Corn yields. In Table 4, corn yields are alike for phosphate rates both for row and broadcast application. The lack of response to phosphate ions is surprising since other experiments in the area in other years showed the need for phosphate (7). In effect, this experiment showed that there is considerable variability by some soil factor

other than phosphate. From a practical standpoint 76 bushels of corn were produced without phosphate on land previously receiving apparently sufficient phosphate.

Relationship of aluminum to corn yields. The regression relationship of aluminum values shown in Table 1 to the corresponding corn yields shown in Table 4 was found to be significant for both row and broadcast applications. In Figure 1, the linear regression function for plots in the experiment with row fertilization is highly significant (t=5.76). This equation is

$$Y = 109 - 0.25 \text{ Al} \qquad (1)$$

where Y is the corn yield expected and Al is the parts per million of aluminum found by 2 N NH_4Ac at pH 4.8.

With broadcast phosphate fertilization, the regression relationship of aluminum on corn yield was also significant (t=2.08). This equation is

$$Y = 87.8 - 0.078 \text{ Al} \qquad (2)$$

with symbols as above. This relationship was less pronounced than for the previous case and is shown in Figure 2.

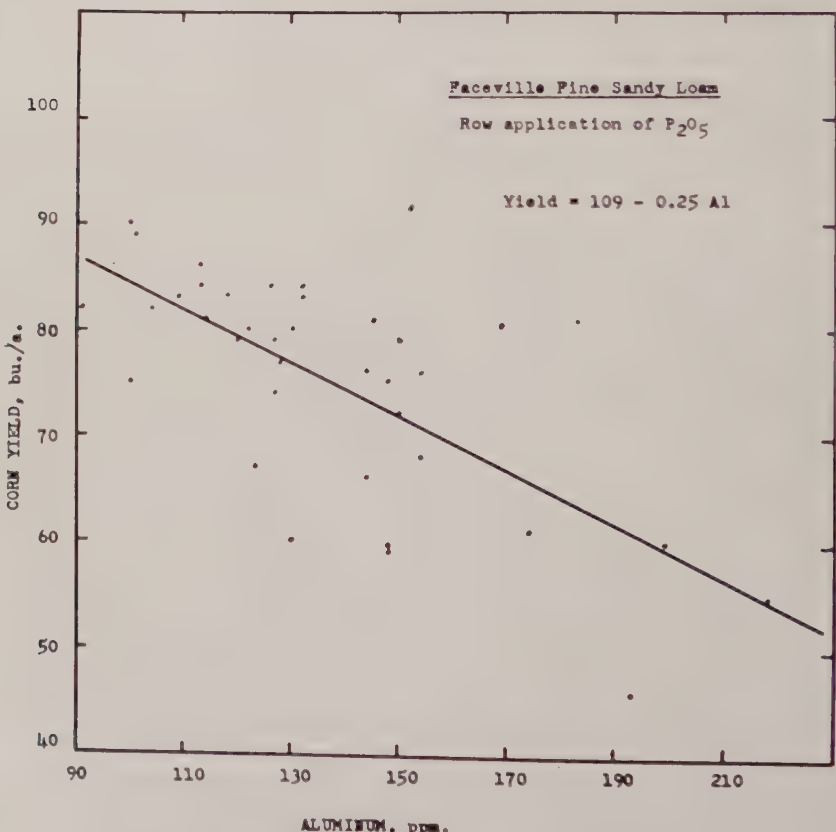

Figure 1.

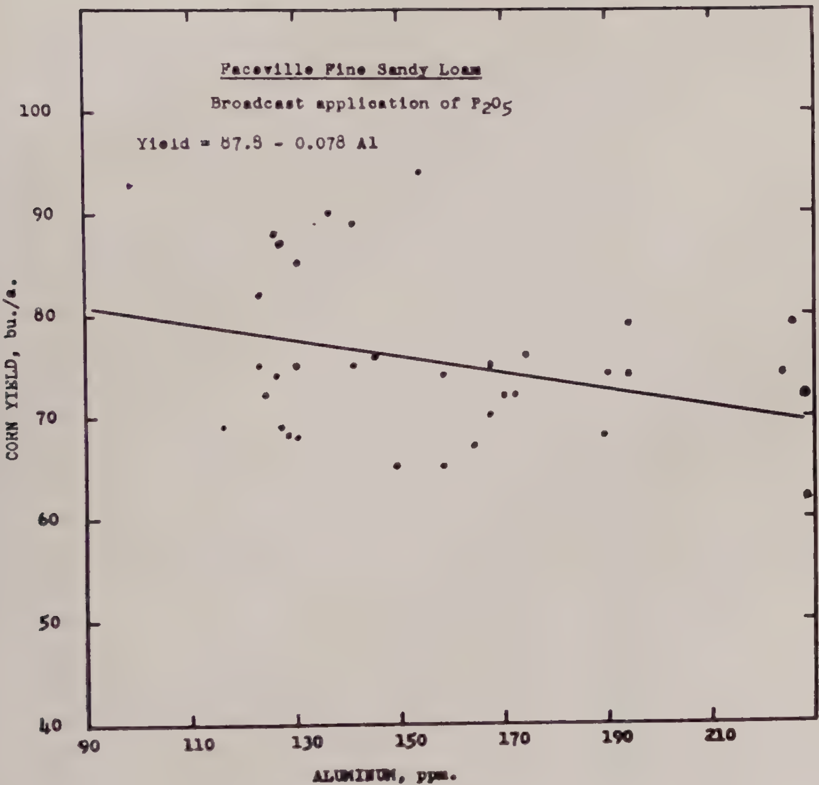

Figure 2.

Other soil analysis. In Table 5, the variability between replicates of soil analyses are shown. The pH in water was 4.88 compared to 4.14 measured in KCl solution. This change in pH was immediate on addition of KCl to the water and did not change appreciably over a period of 72 hours. Extraction of soil samples with normal, neutral KCl also gave the same pH. Titration of this acidity was made with 0.1 N NaOH and showed 0.05 me. (milliequivalents) of total acidity and 0.02 me. of H+ per 100 grams of soil. Hydrogen ion must therefore be a very small component of the exchange complex. At pH 4.8 retention of ammonium ion was one-half that at pH 7.0. At pH 4 the potassium retention was about 2 me. per 100 grams of soil. The calcium and magnesium level in the soil was relatively low since no lime had been applied. Manganese and iron values were about 10 ppm and phosphate 12 ppm as P_2O_5.

Ratio of other ions to aluminum for the phosphate treatments. In Table 6, the various ratios of aluminum to other cations are given. The Ca/Al and P/Al ratios increased with phosphate rate particularly for row application. However, the Mg/Al, Mn/Al, K/Al, Fe/Al ratios were about the same between treatments. If roots feed upon nutrients proportionately to the acetate-extractable amounts, the role

TABLE 5. ANALYSIS OF FACEVILLE FINE SANDY LOAM FOR pH, CATION EXCHANGE CAPACITY, AND IONS EXTRACTED BY NORMAL AMMONIUM ACETATE AT pH 4.8.

Rep.	pH		c.e.c.*			Ions extracted by N NH Ac at pH 4.8 ppm.					
	H_2O	KCl	pH 4.8	pH 7.0	Al	Ca	Mg	K	Mn	Fe	P
1	4.83	4.02	5.86	12.7	138	76	19	58	9.7	11.8	5.1
2	4.80	4.03	5.50	11.8	142	53	14	80	9.8	10.4	4.8
3	4.95	4.25	6.03	12.0	146	55	23	75	8.8	9.6	4.7
4	4.91	4.08	7.23	13.2	149	66	16	74	9.4	7.8	5.3
5	4.92	4.18	6.32	12.3	156	55	16	81	11.2	10.9	7.2
Ave	4.88	4.14	6.19	12.4	146	61	18	74	9.8	10.1	5.4

*Millequivalents per 100 grams of soil determined as ammonium ion retention from 2N NH_4Cl leaching at pH 4.8 and 7.0 with excess removed by alcohol before NH_3 determination.

TABLE 6. ANALYSES OF FACEVILLE FINE SANDY LOAM SHOWING THE RATIOS OF ACETATE EXTRACTABLE IONS TO ALUMINUM AT THE DIFFERENT RATES OF PHOSPHATE FERTILIZATION EITHER AS ROW OR BROADCAST APPLICATION.

(mean of 5 replications)

Method P_2O_5 Applied	Rates of P_2O_5 applied Ratio to Al of other ions extracted by N NH_4Ac at pH 4.8						
	0	45	90	135	180	225	270
				Ca/Al ratio			
Row	0.16	0.22	0.19	0.23	0.63	0.95	0.96
Broadcast	.15	.19	.21	.40	.40	.54	.54
				Mg/Al ratio			
Row	.13	.09	.12	.13	.12	.13	.14
Broadcast	.08	.12	.11	.14	.15	.11	.17
				K/Al ratio			
Row	.45	.49	.52	.73	.48	.68	.59
Broadcast	.42	.42	.36	.38	.44	.56	.62
				P/Al ratio			
Row	.017	.024	.034	.045	.038	.058	.118
Broadcast	.012	.012	.022	.035	.028	.024	.050
				Mn/Al ratio			
Row	.080	.046	.074	.093	.053	.066	.072
Broadcast	.046	.059	.047	.068	.066	.065	.073
				Fe/Al ratio			
Row	.066	.063	.069	.067	.054	.077	.092
Broadcast	.046	.060	.060	.062	.084	.061	.073

of aluminum as a dominant cation is indicated. Since these samples were taken after the corn was mature, the residual values were found. Appreciable amounts of Ca, K and Mg had been taken into the plant and these ratios to aluminum during the growing period might be different than indicated by the soil analysis. Aluminum likely was not toxic in the usual sense but rather was competitive to other cations in the intake of nutrients by the corn plant.

RESIDUAL PHOSPHATE EFFECTS

This experiment was conducted on a heavy Red Bay fine sandy loam grading toward Orangeburg fine sandy loam. Uniform row fertilization was made with 90 pounds of N, 60 pounds of P_2O_5, and 60 pounds of K_2O per acre. The treatments were 0, 45, 90 and 180 pounds of P_2O_5 applied broadcast the year previous. Dixie 18 corn was used. Soil samples were taken from the root zone of the mature corn. Analyses were made as described above.

Aluminum and other soil analysis. In Table 7, corn yields and soil analysis data are given for each plot. This detail is presented since aluminum values need to be understood with respect to variability and other ions extracted. The trend toward higher yields at the 90 and 180 pound rates of residual phosphate was not significant at the 5 percent level. The pH values in water averaged 6.53 compared to 4.33 in dilute KCl solution. Analysis of the KCl leachates for Al-ion showed values decreasing from 80 to 43 ppm as phosphate residual rates increased and titration for H-ion gave 0.05 me. per 100 grams of soil. Cation exchange capacity at pH 4.8 was about one-half that at pH 7.0. With acid ammonium acetate extraction the aluminum values were significantly lower at 200 ppm where residual phosphate at the 90 or 180-pound rate had been applied compared to 388 ppm where none was used. Calcium values were usually above 300 ppm from previous lime application but were not altered by the previous phosphate level. Average values for Mg were 123 ppm which is high for the area, P averaged 162 ppm, Mn was 7.6 ppm, Fe was 8.3 ppm and P at 2.2 ppm, none of which were different between treatments.

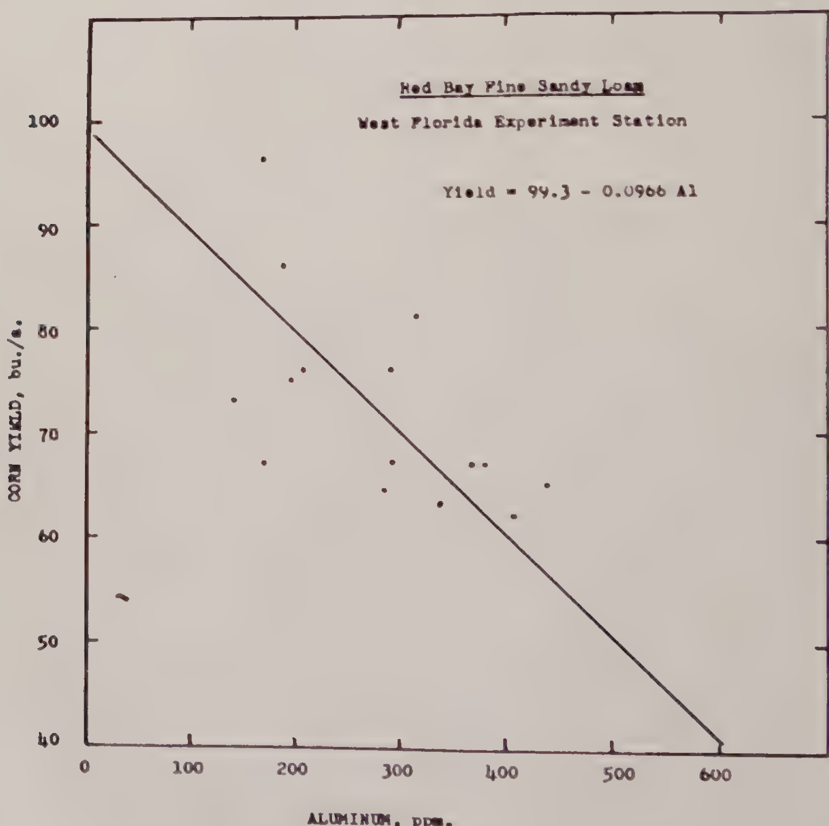

Figure 3.

TABLE 7. Chemical Properties of Red Bay Fine Sandy Loam Sampled in the Root Zone of Mature Corn in a Study of Residual Phosphate Effects and Corn Yields Obtained

Treatment[1]		Reps.	Yield	pH		C.e.c.		Extractable with N NH_4Ac, pH 4.8							N KCl
P_2O_5 in 1957	P_2O_5 in 1958			H_2O	KCl*	pH 4.8	pH 7.0	Al	Ca	Mg	K	Mn	Fe	P	Al
lbs/a	lbs/a		bu/a					ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
None	60 row	1	62	6.23	4.40	5.50	10.70	408	322	117	135	4.8	7.2	1.3	53
		2	65	6.40	4.30	----	----	439	722	148	171	8.0	8.8	1.0	93
		3	63	6.50	4.28	6.03	12.80	336	328	115	202	9.5	5.3	1.1	105
		4	67	6.60	4.43	3.91	8.08	368	328	136	194	8.0	18.0	1.2	69
		Ave.	64	6.43	4.35	5.15	10.53	388	425	129	176	7.6	9.8	1.2	80
45	60 row	1	67	6.65	4.20			291	350	130	160	4.8	6.4	1.5	33
		2	81	6.45	4.25	3.12	9.12	318	433	110	197	4.0	7.2	1.7	59
		3	67	6.43	3.88			380	585	136	175	8.2	7.1	2.1	61
		4	46	6.50	4.18			387	166	116	93	6.4	7.8	1.6	98
		Ave.	65	6.51	4.13			344	384	123	156	5.9	7.1	1.7	63
90	60 row	1	75	6.40	3.95			197	288	62	163	7.6	6.4	2.6	106
		2	76	6.48	3.90			207	356	124	107	4.8	7.6	2.0	62
		3	67	6.60	4.22			170	315	132	153	9.7	8.8	2.0	60
		4	76	6.62	4.61			290	423	124	131	7.9	6.4	3.2	69
		Ave.	73	6.52	4.17			216	346	111	139	7.5	7.3	2.5	74
180	60 row	1	73	6.60	4.43	5.72	9.45	141	366	125	226	9.6	11.6	2.0	26
		2	86	6.65	4.32			190	755	123	152	8.0	4.0	3.0	40
		3	96	6.85	4.80			170	387	135	158	11.1	5.6	4.5	61
		4	64	6.45	4.95			287	484	138	175	8.5	14.2	3.0	44
		Ave.	80	6.64	4.63			197	448	140	178	9.3	8.9	3.4	43
L.S.D. (5%)			N.S.					75	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[1]Uniform row application of 90 pounds of N and 60 pounds of K_2O per acre.

*Neutral normal KCl was used; hydrogen released was titrated as 0.04 milliequivalents per 100 grams of soil.

Corn yields and extractable aluminum relationship. The regression effect of aluminum on corn yields was determined to be highly significant (t=5.52). This relationship is

$$Y = 99.3 - .0966\ Al \qquad (3)$$

where Y and Al represent corn yield and extractable aluminum, respectively. This is plotted in Figure 3. The variability of the aluminum likely resulted from the liming efficiency as well as the phosphate effect in addition to the natural soil variation. Note that the lowest corn yield was obtained where the soil Ca/Al ratio was 0.29 and the highest where this ratio was 2.2. The regression relationship of Ca/Al ratio on yield is highly significant (t=3.73). This linear equation is

$$Y = 55.7 + 9.24\ Ca/Al \qquad (4)$$

where Y is the expected corn yield and Ca/Al the ratio of exchangeable Ca and Al by ammonium acetate at pH 4.8. (See Figure 4).

DISCUSSION AND CONCLUSION

The accumulation of phosphate in applications over a period of years was found to be as aluminum phosphate (8) using the method of Chang and Jackson (3). The specificity of fluoride in dissolving aluminum phosphate might also account for the suitability of strong Bray reagent for determining phosphate in these soils. The present

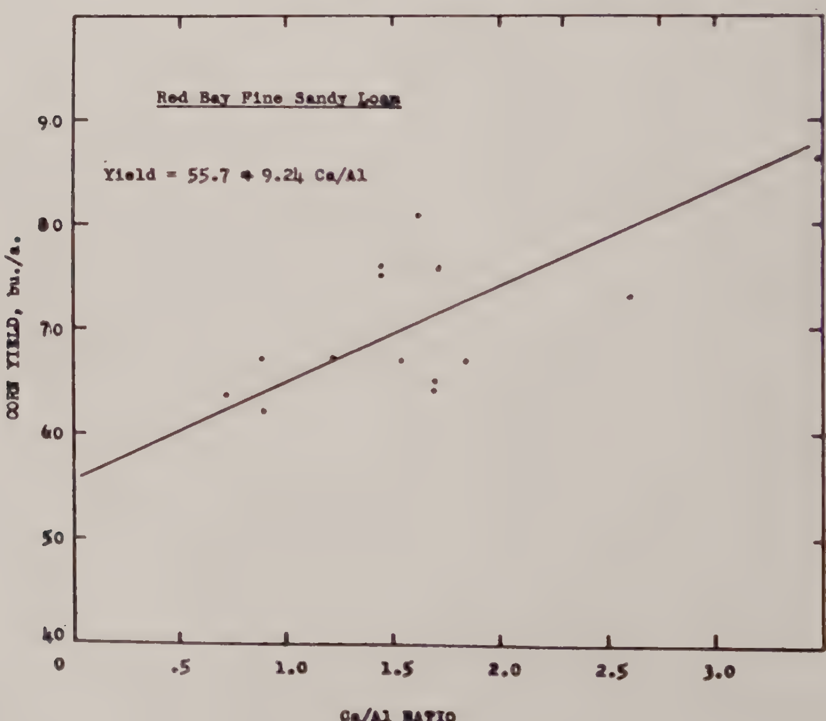

Figure 4.

data showed that easily extractable and presumably exchangeable aluminum was reduced by phosphate additions. The combination of phosphate fixation studies and the exchangeable aluminum reduction fit well into the theory that aluminum phosphate is formed in these processes. Reaction of aluminum with phosphate likely proceeds by the following reaction

$$Al^{+++} + H_2PO_4^- + 2H_2O \rightarrow Al\,PO_4 \,.\, 2H_2O + 2H^+ \qquad (5)$$

The yield data in both experiments showed no response to phosphate application. On the Faceville fine sandy loam the exchangeable aluminum averaged 146 parts per million or about 300 pounds per acre. However, on the Red Bay fine sandy loam, good yields were obtained on soil varying from 170 up to 439 ppm with an average of 261 ppm. Yields averaged 75 bushels on the Faceville and 71 bushels per acre on the Red Bay fine sandy loam. On both soils the regression relationship of aluminum extracted and corn yields was significant. The effect of higher soil aluminum values was to reduce yields. This effect was greater where soil calcium was lower. Similar significant regression relationship for soil Al and Ca Al ratio on corn yields were reported for Norfolk fine sandy loam (5).

The use of soil analysis in determining whether aluminum is high enough to affect yields will require similar regression studies on other soils and other crops. Since each field has more than one soil type, it would be impossible to predict accurately the aluminum status for a crop growing on that area. However, since liming reduces aluminum, as does phosphate, a program of liming and fertilization can control the aluminum to average levels permitting good growth.

The concept that aluminum competes with other nutrients requires some elaboration. If for instance the chances are that a root will meet and absorb 5 aluminum ions for each calcium ion or other nutrient, then calcium intake by the plant might suffer. If, however, fertilization increases the chances of a root meeting calcium ions to be 5 or even 100 times that of the intake of an aluminum ion, then calcium intake might be normal and aluminum effect very much less. Phosphate reaction with aluminum both in the soil and within the plant is quite likely. Here again a plentiful supply of phosphate is likely to reduce an injury by aluminum although this has not been studied in detail. Aluminum on the exchange complex is a natural phenomenon and fertility may be maintained if other nutrients are kept in adequate supply. On soils at West Florida Station crop response to nitrogen, phosphate, lime and potash have been obtained but not to minor elements. These soils are high in both exchangeable aluminum which is an active form and in gibbsite which is probably inert. Yields in this area are above average for the state (9).

LITERATURE CITED

1. Barnette, R. M. The influence of soluble aluminum salts on the growth of wheat seedlings in Shives R_3C_3 solution. N. J. Sta. Rept. 255-258. (1923).
2. Burgess, P. S. Comparison of "active" aluminum and H-ion concentrations of widely separated soils. Soil Sci. 15: 407-412. (1923).
3. Chang, S. C. and Jackson, M. L. Fractionation of soil phosphorus. Soil Sci. 84: 133-144. (1957).

4. Conner, S. D. and Sears, O. H. Aluminum salts and acids at varying hydrogen ion concentrations in relation to plant growth in water cultures. Soil Sci. 13: 23-24. (1922).

5. Fiskell, J. G. A. and Hutton, C. E. Aluminum as a soil fertility factor for corn growth on Norfolk fine sandy loam. Soil Sci. Soc. Amer. Proceedings (Manuscript).

6. Fiskell, J. G. A., Thompson, L. G., Winsor, H. W. and Yuan, T. L. Relative availability to corn of nutrient elements as affected by minor element sources applied to Everglades peat and Norfolk loamy fine sand. Soil Sci. Soc. Amer. Proc. 49: 300-306 (1957).

7. Hutton, C. E., Robertson, W. K. and Hanson, W. D. Crop response to different soil fertility levels in a 5x5x5x2 factorial experiment. I-Corn. Soil Sci. Soc. Amer. Proc. 20: 531-537. (1956).

8. Robertson, W. K. and Hutton, C. E. Retention of fertilizer elements in Red Bay fine sandy loam. Soil Sci. Soc. Amer. Proceedings (Manuscript).

9. Robertson, W. K. Hutton, C. E., Lundy, H. W., Thompson, L. G. and Lipscomb, R. W. Effect of lime on some North Florida soils. Soil and Crop Sci. Soc. Fla. Proc. 17: 72-85. (1957).

10. Yuan, T. L. and Fiskell, J. G. A. Aluminum studies II. The extraction of aluminum from some Florida soils. Soil Sci. Soc. Amer. Proceedings (Manuscript).

Effect of Potash on Yield and Quality of Hamlin and Valencia Oranges[1]

E. J. DESZYCK, R. C. J. KOO, AND S. V. TING[2]

In 1939 an experiment with varied rates of potash was begun on two-year-old orange trees at the Citrus Experiment Station. A progress report (9) was published in 1952 covering results to that time. The present and final report summarizes data on yield, fruit quality and sugar content, tree growth and mineral composition of Hamlin and Valencia trees from 15 to 20 years of age.

EXPERIMENTAL METHODS

Seven levels of potash as outlined in Table 1 have been applied to Valencia and Hamlin trees on rough lemon rootstock. Trees were fertilized with a 4-6-X-4-1-1 mixture prior to 1954 and an 8-0-X-6-0.6-0 mixture since 1954. Each tree received 42 pounds of fertilizer during 1951, 45 pounds during each of the next two years, and since 1954, each Valencia tree received 24, while Hamlin received 39 pounds. The depth to clay ranged from 7 to 8 feet. A guard row of trees separated each plot from adjoining plots. Except for potash, all trees received the same treatment in keeping with good grove practices with no

TABLE 1. EFFECT OF POTASH TREATMENTS ON GROWTH AND YIELD OF VALENCIA AND HAMLIN ORANGES.

Potash in fertilizer %	Tree height[a] Val.	Tree height[a] Ham.	Yield[b] Val.	Yield[b] Ham.	Soluble solids[c] Val.	Soluble solids[c] Ham.
	ft.		boxes/tree		lb./tree	
0	14.9	15.7	3.88	7.12	21.0	30.9
2	15.7	17.0	4.66	8.33	25.9	38.9
5	15.0	16.4	4.83	8.61	25.7	36.8
8	15.6	18.0	4.98	8.72	27.0	40.6
10	16.0	18.0	5.53	8.54	30.5	38.3
12	15.4	17.6	4.75	8.47	25.5	38.0
16	15.5	17.4	5.10	8.40	26.6	37.2
L.S.D. at .05	n.s.	n.s.	.43	.84	3.5	3.9
L.S.D. at .01			.59	1.13	4.7	5.3

[a]Measured on November 21, 1957.
[b]Average yield in boxes (2.2 bu./box)—1951 to 1957.
[c]Average yield for five seasons on random fruit picked during harvest or last sampling date of each season.
n.s. Not significant.

[1]Florida Agricultural Experiment Station Journal Series, No. 862.
[2]Associate and Assistant Horticulturists, Citrus Experiment Station, Lake Alfred, Florida in cooperation with the Florida Citrus Commission.

irrigation. Plots of eight trees each were duplicated except for single and triple plots for the no-potash treatment on Hamlin and Valencia, respectively. Further details of experimental plan, fertilizers, and results up to 1951 have been reported previously (9).

For mineral analysis approximately 100 spring-cycle leaves from non-fruiting stems, and nearly 45 pounds of random fruit were collected at intervals during 1954-55, prepared, and analyzed as described elsewhere (3). Factors of internal fruit quality were measured by the same procedures described by Sites (8). Sugars were determined using a method similar to that proposed by Ting (11). Average size of fruit and its grade were ascertained in the packinghouse at harvest. Weight per fruit, percentage juice, pounds of soluble solids per tree, ratio of soluble solids to acid were calculated. Random and sized fruit were used for sugar analysis, with only random fruit being used for study of internal quality.

RESULTS

Growth and yield.—A summary of the effect of potash fertilization on tree height and production is presented in Table 1. Lowest yield resulted from trees without potash treatment but yield increased significantly (about one box per tree) with the 2 percent potash rate. Increases of this magnitude have not been reported previously in field experiments in Florida (1,6,9). With potash levels between 2 and 16 percent, yield of Hamlin was not affected significantly, although it gradually increased to a maximum for the 8 percent level and then decreased. Valencia also showed a similar trend with some exception. Hamlin trees produced nearly twice as much fruit as Valencia.

Yield as pounds of solids closely reflected fruit production. Potash treatment resulted in raised amounts of solids similar to fruit yield. With increased potash rates, yield of solids was not affected significantly in either variety with one exception. Hamlin trees produced nearly 50 percent more solids than Valencia.

Mineral Analysis of leaves and fruit.—Potassium content of Hamlin and Valencia leaves generally decreased with age, with few exceptions (Table 2). Spring-flush leaves in June contained the maximum amounts of potassium, while the same leaves in February contained the minimum. This trend is in general agreement with that reported by Smith and Reuther (10).

In general, potassium content of the leaves reflected the rate of potash fertilization. More potassium was found in leaves from trees treated with the 16 percent rate than with the 5 percent rate. The largest differences in leaf potassium occurred between the zero and the 5 percent treatments.

As in leaves, the potassium content in the fruit also varied with potash treatments. But unlike leaves, the potassium content of the fruit was fairly uniform over several months.

The nitrogen, calcium, magnesium, and phosphorus contents of the leaves and fruit during 1954-55 are shown in Table 3. In the leaves nitrogen increased while calcium and magnesium decreased with increasing rates of potash fertilization. In the fruit calcium and

TABLE 2. Effects of Potash Treatments and Date of Sampling on the Potassium Content of Hamlin and Valencia Leaves and Fruit During 1954-1955[a].

Sampling Date	Treatment—% K_2O in Fertilizer							
	0		5		8		16	
	Ham.	Val.	Ham.	Val.	Ham.	Val.	Ham.	Val.
				Leaves—%				
6- 1-54	1.28	1.07	2.33	2.28	2.56	2.53	3.10	2.75
8- 1-54	1.04	.93	1.81	2.02	2.03	2.09	2.44	2.51
2- 1-55	.72	.59	1.21	1.37	1.26	1.58	1.67	1.76
10- 1-54	.96	.98	1.39	1.56	1.50	1.53	1.99	2.03
12- 1-54	.71	.65	1.30	1.45	1.50	1.62	1.85	2.00
				Fruit—%				
11- 1-54	.94		1.26		1.52		1.51	
12- 1-54	.86		1.39		1.50		1.62	
1-10-55	.85		1.38		1.42		1.54	
1- 3-55		.71		1.37		1.38		1.46
3- 2-55		.83		1.32		1.34		1.45
4- 5-55		.88		1.46		1.51		1.64
5- 3-55		.84		1.38		1.46		1.51
Statistical significance			Treatment			Sampling date		
Leaves			**			**		
Fruit			**			Valencia** Hamlin n.s.		

[a]Results based on dry matter, and each value is the mean of two plots except for Hamlin on no potash. Spring-flush leaves from non-fruiting stems.
**Significant at 99:1, n.s.—not significant.

magnesium decreased with increasing potash levels, but nitrogen decreased only in Valencia fruit. Phosphorus in leaves and fruit was not affected by potash rates. Hamlin contained more magnesium in both leaves and fruit than Valencia.

Juice composition.—Total soluble solids, titratable acid, ratio of soluble solids to acid, juice percentage, and vitamin C are presented as mean values for five seasons on Valencia, and four seasons on Hamlin (Table 4). Fruit grown without potash contained the lowest acid, vitamin C, and the highest ratio. However, the soluble solids content was the highest in the Valencia (12.2 percent), but the lowest in Hamlin (10.4 percent). With 2 percent potash, acid and vitamin C content were raised and the ratio lowered considerably. In the Hamlin, maximum solids resulted from this rate. When fertilized with potash levels from 2 to 16 percent, solids content was affected adversely. Also, the acid content was increased in the Hamlin but not Valencia, and consequently ratio was decreased in Hamlin only. Vitamin C was also increased in the Hamlin.

In general, total sugars followed the same trends as total soluble solids with potash rates (Tables 4,5). Without potash, reducing and total sugars of Valencia were highest, but non-reducing sugars of both varieties were lowest. With two percent potash, maximum amounts

TABLE 3. Effect of Potash Treatments on the Mineral Composition of Hamlin and Valencia Leaves and Fruit During 1954-55[a].

Potash in fertilizer %	N Ham.	N Val.	Ca Ham.	Ca Val.	Mg Ham.	Mg Val.	P Ham.	P Val.
				Leaves—%				
0	2.57	2.64	3.19	4.13	.65	.56	.131	.131
5	2.79	2.72	3.14	3.01	.51	.47	.125	.139
8	2.76	2.66	3.29	2.86	.48	.45	.132	.136
16	2.94	2.86	2.38	2.50	.38	.36	.134	.140
				Fruit—%				
0	.88	.95	.32	.30	.16	.13	.095	.113
5	.85	.89	.28	.28	.14	.12	.093	.107
8	.86	.90	.26	.23	.14	.12	.093	.108
16	.86	.84	.23	.25	.11	.11	.094	.107
Statistical significance								
Leaves	**		**		**		n.s.	
Fruit	n.s.	**	**		**		n.s.	

[a]Spring-flush leaves from non-fruiting stems sampled August 1, 1954. Hamlin oranges on December 1, 1954, and Valencia oranges on April 5, 1955. Results based on dry matter, and each value is the mean of two plots except for Hamlin on no potash.

**Significant at 99:1.

n.s.—not significant.

TABLE 4. Effect of Potash Treatments on Fruit Quality of Random Hamlin and Valencia Fruit[a].

Potash in fertilizer %	Soluble solids Ham. %	Soluble solids Val.	Acid Ham. %	Acid Val.	Ratio Ham.	Ratio Val.	Juice Ham. %	Juice Val.	Vitamin C Ham. mg/100 ml	Vitamin C Val.
0	10.4	12.2	.90	.91	11.9	14.0	47.9	50.1	56.5	44.9
2	10.8	12.1	1.05	1.06	10.6	12.0	47.3	50.6	60.8	50.7
5	10.7	11.8	1.11	1.06	10.1	11.7	46.6	50.7	62.4	50.8
8	10.7	11.6	1.12	1.06	9.8	11.6	49.0	49.9	62.8	49.8
10	10.6	11.4	1.19	1.06	9.3	11.4	47.8	51.0	63.0	49.7
12	10.6	11.4	1.20	1.07	9.2	11.5	47.6	50.0	64.4	50.5
16	10.5	11.2	1.18	1.04	9.2	11.9	42.9	50.3	63.4	49.1
L.S.D. at 05	.15	.41	.08	.07	.38	.63	n.s.	n.s.	1.9	2.8
L.S.D. at .01	.20	.55	.11	.09	.52	.85	---	---	2.6	3.8

[a]Each Hamlin value is the mean for four seasons, and Valencia for five seasons, in all cases on random fruit.

of the three sugars resulted in the Hamlin. Increasing rates from 2 to 16 percent lowered reducing and total sugars. Roy (7) reported similar sugar trends in Valencia juice with potash treatment, except the values were much lower. Valencia fruit contained considerably more of the three sugars than Hamlin. Random fruit was slightly higher in sugars than sized fruit.

TABLE 5. Effect of Potash Treatments on the Sugar Content of Hamlin and Valencia Oranges During 1953-54[a].

Potash in fertilizer %	Reducing Sugars—% Hamlin Sized	Valencia Sized	Valencia Random	Non-reducing Sugars—% Hamlin Sized	Valencia Sized	Valencia Random	Total Sugars—% Hamlin Sized	Valencia Sized	Valencia Random
0	3.21	4.88	5.60	3.48	4.46	4.43	6.69	9.35	10.03
2	3.54	4.54	4.70	3.75	4.59	4.90	7.29	9.13	9.60
5	3.38	3.98	4.09	3.56	4.77	4.96	6.94	8.75	9.05
8	3.21	3.93	3.90	3.63	4.82	4.92	6.84	8.75	8.82
10	3.10	3.73	3.72	3.60	4.66	4.64	6.70	8.40	8.36
12	3.16	3.89	3.77	3.61	4.73	4.80	6.74	8.63	8.57
16	3.05	3.60	3.67	3.58	4.75	4.51	6.63	8.35	8.18
L.S.D. at .05	.09	.16	.23	n.s.	.23	.35	.28	.27	.36
L.S.D. at .01	.11	.21	.31	----	.31	.47	.33	.37	.48

[a]Each value is the mean of six sampling dates from January to May, 1954, on Valencia, and three samplings from September to November, 1953, on Hamlin.

Fruit size and grade.—Fruit size and grade were influenced by potash levels (Table 6). Weight per fruit as well as the mean diameter was consistently increased as the potash amounts were raised from none to 16 percent. Valencia fruit was considerably more affected and was larger than Hamlin. On the other hand, percentage of fruit passing the U. S. Grade No. 1 was lowered by increased potash levels. Hamlin fruit was less affected by potash treatments than Valencia.

DISCUSSION

Certain weaknesses of this experiment make inadvisable too close interpretation of the data. The plots were only duplicated although they contained eight trees of each variety. According to Jones, Embleton, and Cree (2) at least four replications in plots of this size are required to allow critical evaluation of yield data with potash treatment, while in any experimental design more reliable data are obtained for fruit quality and leaf analysis than for yield.

TABLE 6. Effect of Potash Treatments on Size and Grade of Hamlin and Valencia Fruit[a].

Potash in fertilizer %	Weight/fruit Ham. g.	Weight/fruit Val. g.	Mean Diameter Ham. in.	Mean Diameter Val. in.	U.S. Grade No. 1 Ham. %	U.S. Grade No. 1 Val. %
0	162	179	2.75	2.80	68.2	58.1
2	167	214	2.80	2.96	68.0	48.0
5	177	242	2.87	3.01	66.9	44.0
8	168	236	2.85	3.04	64.2	36.7
10	170	246	2.85	3.08	62.7	32.8
12	185	240	2.87	3.07	62.1	35.5
16	184	247	2.88	3.10	60.6	27.2
L.S.D. at .05	n.s.	19.0	.055	.038	6.8	6.2
L.S.D. at .01	----	25.8	.075	.051	----	8.3

[a]Each value is the mean for six seasons.

Several factors existed during the course of the experiments which may have influenced the reported results. The nitrogen level on a per box basis was generally low. Irrigation was not practiced even during the three years of low rainfall beginning in 1954. In the deep sandy soils subterranean cross-feeding and lateral movement of potash from adjacent plots may have occurred. This makes it difficult to relate the observed effects to definite added rates of potash, even though the added rates did establish different nutrient levels of potash in the tree. Within these restrictions, certain results are fairly clear.

In both Hamlin and Valencia oranges low potash fertilization was beneficial to three juice characteristics; namely, lower acidity, higher ratio of soluble solids to acid, and higher amount of U. S. Grade No. 1 fruit or packout. Low acid and high ratio are important on Hamlin, since this is used generally for fresh fruit in the early season during which time ratio often limits harvest. High ratio is also essential for the Valencia, not so much for early harvest as for adequate ratio for processing of frozen concentrated orange juice. Packout was highest on low potash, and is important for fresh fruit, but is of little consequence for fruit being processed. However, fertilization at very low levels of potash is neither practiced nor recommended on Florida sandy soils since it adversely affects production, fruit size, and other characteristics.

Fruit from trees fertilized with high potash (16 percent rate) as compared to low potash (2 percent rate) generally contained low soluble solids and sugar content, and was large with poor external quality. Also, in the Hamlin high potash appreciably raised acidity and consequently delayed maturity. As fresh fruit, large sizes in Hamlins are beneficial but this is offset by lower solids, late maturity, and low packout. Low external quality is also a serious handicap to the Valencia used for fresh fruit. For processing fruit low solids and sugars are highly undesirable. Therefore, very high potash fertilization is of doubtful value, expensive, and cannot be recommended.

Potash fertilization had some decided effects on fruit yield and other juice characteristics, which together determine yield of soluble solids per tree. Yields of fruit and solids were raised appreciably by all the potash treatments compared with the no-potash treatment. There was little difference in the yields of fruit or soluble solids among the six treatments receiving potash.

Results of this experiment may be related roughly to commercial practice by comparison with leaf analysis. In a recent state-wide survey of nearly 200 commercial Valencia orchards, Koo, Reitz, and Sites (4) reported 1.87 percent potassium as the mean value in the spring-flush leaves picked during August. This potassium content corresponds to the five percent level of fertilization used in this experiment.

The current potash recommendation (5) of 0.4 pound of potash per box of fruit corresponds roughly with the 5 and 8 percent treatments, basing calculations on actual recorded yield. Somewhat lower amounts might possibly be satisfactory, and particularly with Valencia, the lower level might have some advantages. However, the results of this

one experiment do not justify any major change in potash recommendation.

SUMMARY

Results of fruits quality, yield, growth, and mineral analysis were obtained during 1951-57 on 15 to 20-year-old Valencia and Hamlin trees fertilized since 1939 with varied levels of potash. Potash fertilization resulted in higher yield of fruit and pounds of solids. Hamlin trees grew taller and yielded nearly twice as much fruit as Valencia. During 1954-55 potassium content of leaves and fruit reflected rates of potash applications, and decreased with age of the leaves of both varieties. Nitrogen, calcium, magnesium, and phosphorus data are also presented. Fruit quality of Hamlin oranges differed from Valencia with levels of potash used. In Hamlins acidity and vitamin C were markedly raised, whereas in Valencia soluble solids and ratio were lowered substantially. Fruit size was increased with potash rates, but percentage of fruit of U.S. Grade No. 1 was decreased; Valencia oranges were affected appreciably more than Hamlin. Valencia fruit contained higher reducing, non-reducing, and total sugars than Hamlin, but potash levels depressed reducing and total sugars in the juices of both varieties.

LITERATURE CITED

1. Bahrt, G. M. and W. R. Roy. 1940. Progress report of the effects of no potassium and various sources and amounts of potassium on citrus. Proc. Fla. State Hort. Soc. *53*: 26-34.
2. Jones, W. W., T. W. Embleton, and C. B. Cree. 1957. Number of replications and plot sizes required for reliable evaluation of nutritional studies and yield relationships with citrus and avocado. Proc. Amer. Soc. Hort. Sci. *69*: 208-216.
3. Koo, R. C. J. and J. W. Sites. 1956. Mineral composition of citrus leaves and fruit as associated with position on the tree. Proc. Amer. Soc. Hort. Sci. *68*: 245-252.
4. Koo, R. C. J., H. J. Reitz, and J. W. Sites. 1958. A survey of the mineral nutrition status of Valencia orange in Florida. Fla. Agr. Expt. Sta. Tech. Bull. 604.
5. Reitz, H. J., C. D. Leonard, J. W. Sites, W. F. Spencer, I. Stewart, and I. W. Wander. 1954. Recommended fertilizers and nutritional sprays for citrus. Fla. Agr. Expt. Sta. Bull. 536, pp. 4-15.
6. Reuther W., and P. F. Smith. 1951. Relation of fertilizer treatment to fruit quality of Valencia oranges. Proc. Fla. State Hort. Soc. *64*: 29-35.
7. Roy, W. R. 1945. Effect of potassium deficiency and of potassium derived from different sources on the composition of the juice of Valencia oranges. Jour. Agr. Res. *70*: 143-169.
8. Sites, J. W. 1950. The effect of variable potash fertilization on the quality and production of Duncan grapefruit. Proc. Fla. State Hort. Soc. *63*: 60-68.
9. Sites, J. W. and E. J. Deszyck. 1952. Effect of varying amounts of potash on yield and quality of Valencia and Hamlin oranges. Proc. Fla. State Hort. Soc. *65*: 92-98.
10. Smith, P. F. and W. Reuther. 1950. Seasonal changes in Valencia orange trees. I. Changes in leaf dry weight, ash, and macro-nutrient elements. Proc. Amer. Soc. Hort. Sci. *55*: 61-72.
11. Ting, S. V. 1956. Rapid colorimetric methods for simultaneous determination of total reducing sugars and fructose in citrus juices. Agr. and Food Chem. *4*: 263-266.

Growth of Louisiana S1 White Clover Seedlings as Influenced by Soil Additions of Lime and Phosphate*

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INTRODUCTION

Success in establishing white clover in south Florida has been erratic, and poor first year stands and growths are common. A good clover pasture is highly desirable in November, as the growth of pasture grasses at that time is curtailed. It is important, therefore, to obtain early establishment and rapid growth of first year clover plantings.

Most experienced cattlemen appreciate the necessity for good seedbed preparation, proper inoculation of clover seed, liming of acid soils, careful moisture control and elimination of excess shading from the grass. They generally recognize the need for phosphorus, potassium and other essential elements at planting.

Poor growth of clover seedlings usually has been traced to the lack of one of the above factors. Recent experiments described in this report indicate that the fertilizer requirements of clover seedlings may differ from the needs of established stands.

Much research work has been conducted to determine the fertilizer requirements of established clover, but less information is available on the fertilizer need of clover seedlings. The germination and seedlings stages are complicated by the fact that the bacteria necessarily migrate to, and penetrate the seedling roots. These bacteria are known to differ in their nutritional requirements. When clover has reached grazing height and adequate symbiotic relationships established, the bacteria appear to survive satisfactorily.

EXPERIMENTAL

The experiments were conducted on virgin Immokalee fine sand. C. P. grades of calcium carbonate ($CaCO_3$) was used to coat clover seed, monobasic potassium phosphate (KH_2PO_4) used to supply P, and magnesium sulfate ($MgSO_4$) for Mg. All other fertilizer materials were commercial grades. The ammoniated superphosphate was a 6.5-15-0 formula. The seed was coated with powdered $CaCO_3$ with gum arabic as the sticker. An excess of this material in 30 to 40% aqueous solution was applied to the seed and then mixed thoroughly until all seed coats were moist. After adding an excess of $CaCO_3$ and remixing, the mixture was allowed to dry and the lime coated seed were screened to remove excess lime. Physical characteristics of the hi-calcic lime and rock phosphate used are described in a previous paper (3). pH determinations made on aqueous solutions (1:5 by

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volume) of the 0-10-20, 20% superphosphate, ammoniated superphosphate, and rock phosphate used in these tests were found to be 2.7, 2.7, 4.2, and 6.3, respectively. The materials were stirred vigorously, allowed to settle, and pH was then determined in the clear solution.

Soil analyses were obtained by employing the methods of Forsee and Ozaki (2) and the statistical procedures of Patterson (4) were used.

A. GREENHOUSE EXPERIMENT

Procedure

All the 1-gallon glazed pots received a rate of 500 pounds of 0-8-24 containing 1% CuO, MnO, ZnO, and B_2O_3 per acre, mixed thoroughly with the soil. The formula was made from 20% superphosphate, 60% muriate of potash, borax, copper sulfate, manganese sulfate, and zinc sulfate. Magnesium sulfate at a rate of 100 pounds per acre was added to all pots. Treatments listed in Table 1 included the applications of hi-calcic lime, rock phosphate, ammoniated superphosphate, and gypsum. When hi-calcic lime and ammoniated superphosphate were applied to the surface, they were sprinkled over the seed and soil surface prior to covering the seed with about one-quarter inch of soil. The only difference among 11 pairs of treatments was the addition of Mo to one group. This was accomplished by soaking seed in a one percent aqueous solution of sodium molybdate for 30 minutes prior to planting. The experiment as planned consisted of 22 treatments, with 4 replications. Since there was no response to Mo, results from the similar pairs of treatments were combined for statistical purposes, making 11 treatments and 8 replications.

Commercial legume inoculant was sprinkled over the seed, prior to covering with soil, to assure an adequate supply of bacteria. All seed were planted in a circle approximately equidistant from the center and from the walls of the pots.

Adequate moisture was maintained at all times by using Pyrex glass-distilled water. The soil had an original pH of 4.75, and 0.5*N* acetic acid extractable Ca and Mg contents of 60 and 40 pounds per acre, respectively. The log of the experiment follows:

1. December 9, 1957—seeded all pots after fertilization and liming.
2. January 7, 1958—rated seedlings in all pots: 1=none to poor,
3. January 9, 1958—measured the length of three unifoliate leaf petioles per pot.
   2=poor to fair, 3=fair to good, and 4=good to excellent
4. January 10, 1958—applied KH_2PO_4 to all pots at a rate of 20 pounds of P_2O_5 per acre.
5. February 3—harvested clover from treatments 10 and 11.
6. March 7—harvested clover from all treatments.
7. April 4—harvested clover from all pots and obtained soil samples.

RESULTS

Within a month it was obvious that certain treatments were having a very beneficial effect on the growth of the seedlings, compared to what might be considered the standard treatment, i.e. a rate of 500

pounds of 0-8-24 plus 2,000 pounds of hi-calcic lime per acre. Visual growth ratings and petiole length measurements obtained about one month after seeding indicated that 2000 pounds of rock phosphate, and 500 pounds of hi-calcic lime plus 200 pounds of ammoniated superphosphate per acre were superior treatments. Yields presented in Table 1, substantiated these findings. Good growth responses were also obtained from the 1000-pound rock phosphate treatment. Figure 1 shows the extreme growth differences resulting from several of the treatments. The addition of 20 pounds of P_2O_5 per acre about one month after planting did not have a stimulating effect on the clover. There was evidence that P was made less available to the seedling roots by the addition of lime. A trend of larger early production of clover harvested March 7 resulted from 500 and 1,000 pound applications per acre of hi-calcic lime compared to the 2,000 pound rate. This trend was reversed at the April 4 harvest. Yields obtained March 7 were 1.45, 1.36, and 0.70 grams per pot, respectively, while those for April 4 were 1.90, 2.19, and 2.30 respectively.

No responses were obtained from the use of gypsum or from 200 pounds of hi-calcic lime per acre.

Results of soil analyses are shown in Table 1. These data were

Figure 1.—Louisiana S1 white clover seeded December 9, 1957, and photographed 53 days later. Each pot received a uniform rate of 500 pounds of 0-8-24 per acre plus adequate minor elements. Differential treatments were: (1) O lime, (2) lime-coated seed, (3) hi-calcic lime—1,000 lbs/A, (4) hi-calcic lime—2,000 lbs/A, (5) lime-coated seed + rock phosphate—500 lbs/A, (6) lime-coated seed + rock phosphate—1,000 lbs/A, (7) lime-coated seed + rock phosphate—2,000 lbs/A, and (8) hi-calcic lime—500 lbs/A + ammoniated superphosphate—200 lbs/A, surface applied.

TABLE 1.—THE EFFECTS OF LIME AND PHOSPHORUS SOIL APPLICATIONS ON SOIL ANALYSES AND ON THE YIELDS OF LOUISIANA S1 WHITE CLOVER GROWING IN THE GREENHOUSE ON VIRGIN IMMOKALEE FINE SAND.

Treatment	Seed[1]	Dry Weight Yield				Soil Analyses 1-4-58			
Material—rate, lbs/A	Lime	grams per pot				pH	Ca	P	Mg
	Coated	2-3-58[2]	3-7-58	4-4-58	Total			lbs/A	
1. Gypsum—1,000	+		0.05	0.89	0.94	4.43	60	3.3	26
2. None	+		0.20	0.84	1.04	4.58	11	3.8	26
3. Hi calcic lime—200[3]	—		0.28	1.49	1.76	4.74	20	4.3	26
4. None	—		0.28	1.16	1.45	4.58	11	4.0	22
5. Hi calcic—2,000	—		0.70	2.30	3.00	5.95	513	3.5	50
6. Rock phosphate—500	+		1.18	1.68	2.85	4.76	69	3.3	30
7. Hi calcic—1,000	—		1.36	2.19	3.55	5.31	359	3.3	55
8. Hi calcic—500	—		1.45	1.90	3.35	4.88	115	3.8	43
9. Rock phosphate—1,000	+		1.76	1.63	3.39	4.88	114	4.4	34
10. Hi calcic lime—500	—	2.05	2.48	2.84	5.14	4.94	89	3.8	35
11. Amm. Superphos.—200[3] Rock phosphate—2,000	+	3.83	5.38	4.14	9.51	4.76	348	7.8	32
L.S.D. .05		------	1.07	0.56	0.40	0.16	115	0.11	8.5
L.S.D. .01		------	1.43	0.74	0.52	0.21	152	0.14	11.3

[1] + seed coated with C.P. grade calcium carbonate.
[2] Yields are included in the March 7 harvest, when all pots were harvested, and also in the total yields.
[3] Surface applied. Other treatments were surface applied.

obtained from soil that had produced two or three cuttings of clover. Therefore, those treatments producing the highest yields also were those in which the soil minerals had been depleted most by "cropping." Soil pH alone was not indicative of the potential clover seedling growth that occurred. In this experiment maximum yields were obtained when the soil pH was about 5.0. This does not mean, however, that rapid initial growth will occur if the soil pH in the seed zone is low. Relatively high levels of Ca and P in the soil were of primary importance. The soil from the maximum yielding treatment, rock phosphate—2,000 pounds, contained relatively high soil Ca and P contents.

B. FIELD EXPERIMENT

Procedure

Because of the remarkable clover growth responses to phosphorus, and the apparent effect that large additions of lime seemed to have on reducing phosphorus availability, a field experiment was designed to confirm the greenhouse results. The effect of placement of materials was also studied and the effect of molybdenum.[2] Five by five feet plots of soil were used which had a pH of 4.9 to 5.4 and 0.5N acetic acid extractable Ca and Mg contents of 60 and 10 to 35 pounds per acre, respectively. The plots in which materials were to be incorporated in the soil were fertilized February 6, 1958, with 500 pounds of 0-10-20 per acre. Fifteen pounds each of copper and manganese sulfate, and 10 pounds of zinc sulfate and borax per acre were applied with the 0-10-20. Certain rock phosphate and hi-calcic lime treatments were also applied February 6 and incorporated with the soil to a depth of 4 or 8 inches. Surface fertilizer and lime treatments were made February 12, and all plots were seeded at the rate of 10 pounds per acre February 27, 1958. All plots except numbers 33 and 34 received the basic fertilization rate of 500 pounds of 0-10-20 per acre. Certain of the treatments included the use of lime-coated seed as indicated in Tables 2,3,4. There were 34 treatments, each replicated three times. Twelve basic treatments were duplicated, with and without molybdenum, to test its effect. After no differences were found as a result of the Mo additions, these 12 duplicate treatments plus a duplicate phosphate treatment (Nos. 5 and 6) were combined to give the advantage of 6 replications for statistical analyses of the data. Treatments are listed in Table 2. The column under placement indicates whether the special materials (lime, rock, phosphate, etc.) and 0-10-20 were applied to the surface (s) or incorporated to a depth of 4 or 8 inches. The column under seed indicates whether (+) or not (-) lime and Mo were added to the seed prior to planting.

A log of the experiment follows:

April 4, 1958—(37 days from seeding) Visual ratings were made of the clover growth.

April 24,—(57 days) Harvested all plots by clipping a one square foot area per plot.

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[2]Aided by a Grant from the Climax Molybdenum Corporation.

Table 2—Key to Fertilizer and Lime Treatments Applied to Virgin Immokalee Fine Sand in a Field Experiment with Louisiana S1 White Clover.

Special Treatment	Placement: Inches Incorporated or Surface Applied.		Seed	
Material—rate, lbs/A	Special Treatment (t)	Fertilizer (F) 0-10-20	Lime Coated (LC)	Mo
1. Hi calcic lime—2000	4	4	—	+
2. Hi calcic lime—2000	8	8	—	+
3. Hi calcic lime—2000 + rock phosphate—2000	4	4	—	+
4. Hi calcic lime—2000 + rock phosphate—2000	8	8		+
5. Hi calcic lime—2000 + superphosphate (20% P_2O_5)—250	4,4	4		+
6. Hi calcic lime—2000 + superphosphate (20% P_2O_5)—250	4,S	4	—	+
7. Hi calcic lime—2000 + rock phosphate—2000	4	4	—	—
8. Hi calcic lime—2000 + rock phosphate—2000	4	S	—	+
9. Check (0-10-20—500)	0	S	+	+
10. Check (0-10-20—500)	0	S	+	—
11. Hi-calcic lime—200	S	S	—	+
12. Hi-calcic lime—200	S	S	—	—
13. Ammoniated superphosphate (6.5-15-0)—200	S	4	+	+
14. Ammoniated superphosphate (6.5-15-0)—200	S	4	+	—
15. Rock phosphate—500	S	4	+	+
16. Rock phosphate—500	S	4	+	—
17. Rock phosphate—500	4	4	+	+
18. Rock phosphate—500	4	4	+	—
19. Rock phosphate—1000	4	4	+	+
20. Rock phosphate—1000	4	4	+	—
21. Rock phosphate—2000	4	4	+	+
22. Rock phosphate—2000	4	4	+	—
23. Hi calcic lime—500	4	4	—	+
24. Hi calcic lime—500	4	4	—	—
25. Hi calcic lime—1000	4	4	—	+
26. Hi calcic lime—1000	4	4	—	—
27. Hi calcic lime—1500	4	4	—	+
28. Hi calcic lime—1500	4	4	—	—
29. Hi calcic lime—2000	S	S	—	—
30. Hi calcic lime—2000	4	4	—	—
31. Rock phosphate—500 + fritted trace elements—30	S	S	—	—
32. Rock phosphate—1000 + fritted trace elements—30	S	S	—	—
33. Wire grass ash—2000 (fresh weight)	S	0	+	+
34. Wire grass ash—4000 (fresh weight)	S	0	+	+

TABLE 3.—THE EFFECTS OF VARIOUS SOIL APPLICATIONS OF LIME AND PHOSPHORUS TO VIRGIN IMMOKALEE FINE SAND ON THE VIGOR AND DRY WEIGHT YIELDS TO LOUISIANA S1 WHITE CLOVER.

Treatment[1]	Place[1]		Seed[1]		Rating[2]				Yield—lb/A.	
Material—rate, lbs/A	T.	F.	I.C	Mo	4-4	5-28	6-20	8-1	4-24	5-28
23. HC—500	4	4	—	+	1.8	3.0	2.7	1.3	80	990
27. HC—1500	4	4	—	+	2.2	3.2	2.5	2.2	290	1120
1. HC—2000	4	4	—	+	2.2	4.0	3.5	3.0	340	1760
25. HC—1000	4	4	—	+	2.0	3.3	2.8	3.0	380	1220
16. RP—500	S	4	+	—	2.7	4.0	3.7	1.0	380	1790
2. HC—2000	8	8	—	+	2.3	4.0	3.5	2.3	390	1730
15. RP—500	S	4	+	+	2.6	4.0	4.0	1.0	500	1890
26. HC—1000	4	4	—	—	2.1	4.0	3.8	2.7	610	1570
9. Check (O-10-20)	0	S	+	+	3.0	1.8	1.5	1.2	620	480
10. Check (0-10-20)	0	S	+	—	3.1	1.7	1.0	1.0	620	350
4. HC—200 + RP—2000	8	8	—	+	2.7	3.2	2.3	3.0	730	990
24. HC—500	4	4	—	—	2.2	4.0	3.7	1.7	740	1790
18. RP-500	4	4	+	—	3.1	2.2	1.7	1.3	750	860
32. RP—1000 (+FTE)	S	S	—	—	3.3	2.7	1.5	1.0	810	770
17. RP—500	4	4	+	+	3.2	1.8	1.2	1.3	860	670
31. RP—500 (+FTE)	S	S	—	—	3.0	1.3	1.5	1.0	920	320
19. RP—1000	4	4	+	+	3.2	2.5	1.8	1.7	950	1020
7. HC—2000+rock phos.—2000	4	4	—	—	2.4	2.2	2.0	4.0	950	860
28. HC—1500	4	4	—	—	2.3	1.8	2.0	2.5	960	640
30. HC—2000	4	4	—	—	2.9	2.7	1.5	2.3	1010	800
29. HC—2000	S	S	—	—	2.9	3.7	2.5	2.8	1080	1500
12. HC—200	S	S	—	—	3.1	3.5	2.5	2.0	1270	1280
14. Amm. super.—200	S	4	+		3.7	1.8	1.3	1.0	1360	380
3. HC—2000 + RP—2000	4	4	—	+	2.9	2.7	1.7	3.2	1420	610
8. HC—2000 + RP—2000	4	S	—	+	3.0	2.8	2.7	4.0	1480	1340
20. RP—1000	4	4	+	—	3.7	3.5	2.8	1.2	1490	1180
13. Amm. super.—200	S	4	+	+	3.6	2.7	2.0	1.3	1570	900
6. HC—2000 + super.—250	4,S	4	—	+	3.6	3.3	3.0	3.5	1700	1250
22. RP—2000	4	4	+		3.7	1.0	3.2	2.0	1860	1570
21. RP—2000	4	4	+	+	4.0	3.0	2.2	2.0	2490	1220
5. RC—200 + super.—250	4,4	4	—	+	3.7	1.8	1.5	3.7	2540	800
11. HC—200	S	S	—	+	3.1	2.5	1.3	1.3	2660	830
33. Wire grass ash—2000	S	0	+	+	1.1	....	....	1.0		
34. Wire grass ash—4000	S	0	+	+	1.0	....	....	1.0		
L.S.D. .05					0.6	0.5	1.0	2.1	1080	550
L.S.D. .01					0.9	0.7	1.4	2.8	1450	730

[1]See Table 2 for details.

[2]... follows: 1 = none to poor, 2 = poor to fair, 3 = fair to good and 4 = good to excellent.

April 28,– (61 days) Soil samples were obtained.
May 28,– (91 days) Visual ratings were obtained.
May 28,– (91 days) Harvested all plots.
June 17,–Sprigged pangolagrass into the experimental area.
June 18,–Seepage irrigated the experimental area.
June 20,– (114 days) Visual ratings were obtained.
June 20,–All plots were fertilized with a rate of 100 pounds of muriate of potash per acre.
July 11,–Flat-hoed the large weeds from all plots with a minimum amount of soil disturbance.
August 1,– (156 days) Visual ratings were obtained.

Ratings and yield data are presented in Tables 3 and 4; the latter after combining for statistical purposes the + and − Mo treatments. Data in Table 3 are averages of three replications, while those in Table 4 are averages of 6 replications. Molybdenum did not stimulate clover growth in this experiment. Treatments 33 and 34 consisted of wiregrass ash obtained from burning 1 and 2 tons, respectively, of fresh material per acre. The ash was spread on the soil surface in the appropriate plots. Ratings were based on clover growth and vigor: 1=none to poor, 2=poor to fair, 3=fair to good, and 4=good to excellent. Yields were obtained by clipping the clover about 2 inches above the soil surface in a one square foot area in each plot.

Results

Initial Rating and Yield—The first ratings indicated that large growth differences existed. Initially, better growth was associated primarily with higher rates of P. High first yields usually received good growth ratings. However, several treatments that had received a vigorous rating April 4 failed to maintain the growth rate through the April 24 harvest. This trend generally was true of treatments receiving limited quantities of lime. Other treatments beginning with a relatively slower growth rate (recorded April 4) began to grow more rapidly by the April 23 harvest. It appeared that initial growth was dependent primarily on adequate available P if sufficient small quantities of lime, as supplied by lime-coating the seed, were present. Relatively large quantities of lime in close association with soluble soil P and the seedling roots seemed to reduce P availability. Several examples of these trends are evident when the following comparisons are made: (1) Addition of 2,000 pounds of lime to the check treatments did not result in increased yields, (2) the application of 2,000 pounds of lime plus an additional 250 pounds of superphosphate resulted in increased yields and (3) addition of 2,000 pounds of lime to the 2,000 pound rock phosphate treatments resulted in lower yields than those for the 2,000 pound rock phosphate treatment.

Two treatments, ammoniated superphosphate and hi-calcic lime both at 200 pounds per acre, require special mention since they do not entirely fit the pattern described above. The ammoniated superphosphate supplied about 13 pounds of N and 26 pounds of additional P_2O_5 and had a pH in aqueous solution of 4.2. This treatment

added extra phosphate, was less acid than the 0-10-20, and supplied a small amount of nitrogen. It is believed that all three factors were helpful in producing larger initial ratings and yields. The 200-pound hi-calcic lime treatment was believed to have produced larger initial yields than the check treatment because it supplied sufficient Ca to maintain the original moderately rapid growth for a longer period of time.

The growth differences that occurred can not be attributed to the effect of soil pH, per se, as measured by 0 to 6-inch borings. Almost identical initial ratings and yields were obtained when the soil pH was 4.5 or 5.1; low ratings and yields could be found where soil pH values were either low or high. It should be emphasized that those treatments not receiving broadcast applications of lime received seed that were coated with lime. Lime coating the seed would be important to assure a temporary relatively higher pH and soil Ca content in a restricted zone where the seedling roots and bacteria are, but would not be expected to markedly interfere with P availability.

There were several other observations and results of secondary interest that can be summarized. (1) Wire grass ash did not supply sufficient quantities of nutrients for clover growth. (2) There was no difference in growth whether 2,000 pounds of hi-calcic lime was applied to the surface or incorporated into the soil to a depth of 4 or 8 inches. (3) The addition of fritted trace elements did not increase the initial ratings or yields of the 500 or 1,000 pounds rock phosphate treatments.

Clover Growth After the First Harvest—All plots were harvested May 28, about a month following the initial harvest. It is evident from the yield data presented in Tables 3 and 4 that rapid growth rates between the first and second harvest were not limited entirely to those treatments that produced the most rapid growth during the period from seeding to the first harvest.

Growth ratings were obtained May 28, June 20, and August 1 and are reported in Tables 3 and 4. Ratings among dates are comparable since the same rating system was used each time. The rating information presented in Table 4 is presented graphically in Figure 2 wherein it is possible to observe growth trends to August 1. The differences in clover growth among treatments, observed on August 1, were not markedly different when the plots were observed the last of August. This indicated that certain treatments were more beneficial for summer "live-over" than others.

The rating curves in Figure 2 follow four general patterns. (1) Rock phosphate treatments alone produced good early growth, but little or no growth in the early summer. In this group also should be included the check, ammoniated superphosphate, and 200 pounds hi-calcic lime treatments, although clover from these failed to grow much after the first rating. (2) Clover receiving hi-calcic lime rates of 500, 1,000, 1,500, and 2,000 pounds per acre failed to grow rapidly at first, but grew more rapidly in May. Plots receiving 500 pounds of hi-calcic lime per acre were growing less rapidly by August. The plots receiving 1,000, 1,500, or 2,000 pounds of hi-calcic lime per

TABLE 4.—The Effects of Various Soil Applications of Lime and Phosphorus to Virgin Immokalee Fine Sand on the Vigor and Dry Weight Yields of Louisiana S1 White Clover.

Treatment[1]		Place[1]		Seed[1]	Rating[2]				Yield-lbs/A	
Material-rate, lbs/A		T.	F.	I.C	4/4	5/28	6/20	8/1	4/24	5/28
23,24.	NC—500	4	4	—	2.0	2.3	1.5	1.5	410	500
15,16.	RP—500	S	4	+	2.6	1.6	1.3	1.0	440	500
25,26.	HC—1000	4	4	—	2.1	3.2	2.8	2.8	500	940
27,28.	HC—1500	4	4	—	2.3	3.0	2.5	2.3	620	1260
9,10.	Check (0-10-20)	0	S	+	3.1	1.8	1.3	1.1	620	1070
1,30.	HC—2000	4	4	—	2.6	3.0	2.4	2.7	670	420
17,18.	RP—500	4	4	+	3.2	2.3	1.9	1.3	810	1100
3, 7.	HC—2000 + RP—2000	4	4	—	2.7	4.0	3.8	3.6	1180	1820
19,20.	RP—1000	4	4	+	3.4	2.0	1.8	1.4	1220	720
13.14.	Amm. Super—200	S	4	+	3.6	2.4	1.6	1.2	1470	820
11,12.	HC—200	S	S	—	3.1	3.0	2.4	1.7	1970	960
21,22.	RP—2000	4	4	+	3.8	3.6	2.5	2.0	2180	1390
5,6 .	HC—2000 + Super.—250	4,S	4	—	3.6	4.0	3.6	3.6	2275	1760
	L.S.D. .05				0.5	0.8	0.7	1.3	770	360
	L.S.D. .01				0.7	1.1	0.9	1.7	1070	500

[1]See Table 2 for details.
[2]Clover growth rated as follows: 1 – none to poor, 2 poor to fair, 3 – fair to good, 4 = good to excellent.

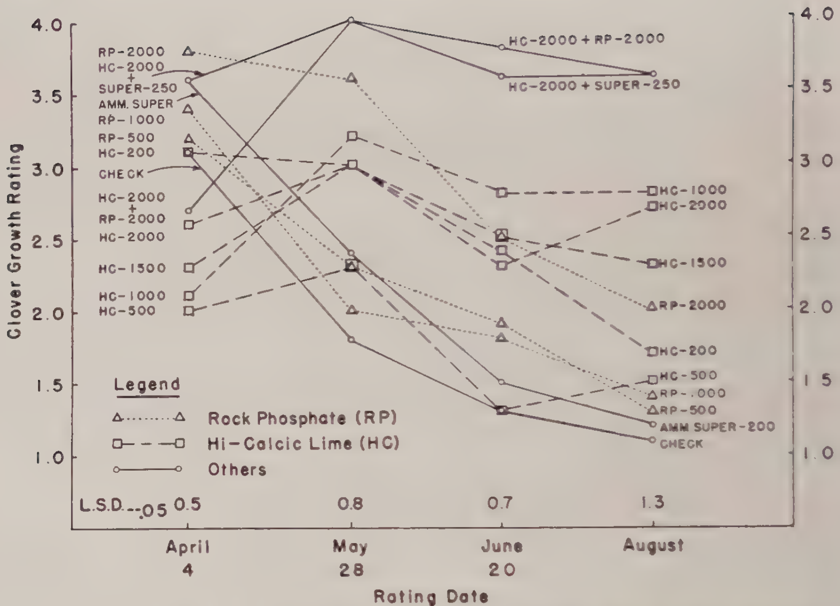

Figure 2.—Ratings of Louisiana S1 white clover growth and vigor obtained at four dates. Seeded February 27, 1958. Rating scale: 1 = none to poor, 2 = poor to fair, 3 = fair to good, 4 = good to excellent.

acre maintained a slightly increased growth rate over that in April. (3) Clover receiving 2000 pounds of lime and additional P from the less soluble source (rock phosphate) initially grew slowly but continued to grow more rapidly, and by June was maintaining a rapid growth rate. (4) Clover receiving 2000 pounds of lime and additional soluble P (superphosphate) grew rapidly throughout the period. Pictures showing growth differences April 18 and June 20 as a result of 5 major treatments are presented in Figure 3.

DISCUSSION

The fertilizer and lime requirements of established white clover growing on Florida flatwoods soils have been rather extensively investigated. However, little work has been done in connection with the nutritional requirements of clover seedlings. Blaser, Volk and Smith (1) in 1941 showed that the lime and P requirements of different legumes were not similar. They used several rates of lime and P, supplied from different sources. Although some excellent data are presented that show the contents of the cations and N in the plants, yield results are difficult to interpret since all plots were seeded with a mixture of white and bur clover seed. The large variation in the per cent stand of each variety on plots receiving different treatments made it difficult to assess the white clover growth accurately. Their check treatment consisted of 2000 pounds of hi-calcic lime, 600 pounds of superphosphate, and 100 pounds of muriate of

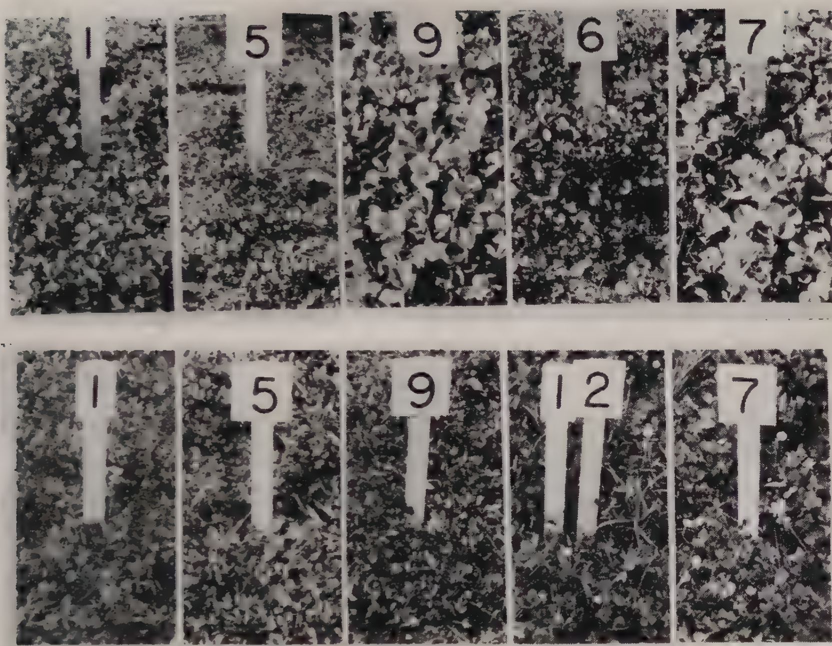

Figure 3.—Top and Bottom Photographs obtained April 18, and June 20, 1958, respectively. All Louisiana S1 clover planted February 27, 1958. Treatments in addition to the uniform rate of 500 lbs/A of 0-10-20 plus adequate minor elements to all plots were: (1) check, (5) hi-calcic lime—2000 lbs/A, (9) rock phosphate—2000 lbs/A (6,12) hi-calcic lime—2000 lbs/A + rock phosphate—2000 lbs/A, and (7) hi-calcic lime—2000 lbs/A + 20% superphosphate—250 lbs/A. All plot markers were the same height above the ground. Treatments (1) and (9) were planted with lime-coated seed.

potash per acre. The relatively high P application was considerably in excess of that used by most ranchers in southern Florida, but probably not excessive when the needs of clover seedlings are considered.

Supplying adequate nutrients for maximum clover seedling growth seems to be critical the first month after planting. During this period the N fixing bacteria are multiplying and migrating to and into the seedling roots. If environmental conditions are optimum and soil nutrients are adequate, rapid bacterial migration, penetration, and multiplication will occur. Furthermore, if these conditions are optimum for root growth, there will be a larger root distribution with possibly less distance for bacterial migration than if nutrients are inadequately supplied. Soon after the penetration of the roots by bacteria, the fixation of N from the atmosphere begins and the clover plants are supplied with the needed N.

Reasons for improper supplies of nutrients for first year clover stands appear to be three-fold. (1) Large quantities of P are needed. Current Experiment Station recommendations include using 60 to 98 pounds P_2O_5 per acre on virgin acid sandy soils at planting, but

only 40 to 60 pounds per acre (the amount recommended for established clovers) are applied by most ranchers. Maximum yields were obtained in this test with the highest rate of soluble P used, 100 pounds of P_2O_5 per acre. (2) Recommendations of up to 6000 pounds of lime per acre have been made for these soils. In view of the effect that large quantities of lime may have on depressing the availability of P to clover seedlings, large lime applications should be reduced, or they should be supplemented by even larger P additions. (3) The difficulty of uniform lime and P distribution makes it almost impossible for optimum quantities of these materials to be in adequate supply over the entire field. Undoubtedly there will be zones of high P, low P, high lime, low lime, and all combinations. Only those areas having a relatively large supply of P and adequate lime (and other essential nutrients) will produce rapid first year growth. Part of the distribution difficulty can be overcome by increasing the rate of P and trying to obtain more uniform coverage with the lime.

From observations made following farmers' fertilization and liming practices plus the results of the two experiments presented here, it is believed that the lack of adequate available P at seeding time on virgin acid soils has been the primary nutritional factor responsible for poor white clover growth. This same condition quite possibly could be the reason for poor "summer live-over" of most relatively new clover plantings. Further proof of the above statements was obtained by observing the consistent excellent initial white clover growth on areas previously planted to vegetables. Many of these areas did not receive the large quantities of lime recommended for clover, but all received considerably more P than generally would be applied to clovers.

CONCLUSIONS

1. The rapidity of white clover growth during the first month to six weeks was influenced primarily by the supply of available P when sufficient small quantities of lime were in the seed zone.

2. Hi-calcic lime at 2,000 pounds per acre depressed the initial rate of growth unless larger rates of P were used. Applications of one ton of hi-calcic lime required at least 100 pounds of P_2O_5 per acre to insure maximum growth.

3. After the initial growth stage, the need for lime became more critical and the highest applications of lime and P were needed to maintain a good to excellent clover growth rate through summer.

4. Rock phosphate applications at 2,000 pounds per acre, when seed were coated with lime, produced good clover growth in the greenhouse and field.

5. Initial clover growth was stimulated markedly by applications of 200 to 250 pounds of ammoniated superphosphate per acre.

6. There was no difference in growth when 2,000 pounds of lime per acre was surface applied, or incorporated to depths of 4 or 8 inches.

7. No growth responses were obtained from additions of Mo.

REFERENCES

1. Blaser, R. E., Volk, G. M., and Smith, F. B. 1941. The yield, composition, and nodulation of several clover varieties as affected by sources of calcium and phosphorus in combination with other fertilizers on several soils. Soil Sci. Soc. Amer. Proc. 6:298-302.
2. Forsee, W. T. Jr., and Ozaki, Charles T. 1954. Rapid laboratory methods for the analysis of soil and plant tissue samples. Everglades Station Mimeo Report 55-6.
3. Kretschmer, Albert E. Jr., Hayslip, N. C., and Ozaki, C. T. 1957. Soil and Crop Sci. Soc. Fla. Proc., 17:274-286.
4. Patterson, D. D. 1939. Statistical Technique in Agricultural Research. McGraw-Hill Book Company. New York.

Effects of Population Trends and Farm Mechanization on Production of United States Feed and Food Supplies[1]

F. T. Boyd[2]

For many years food production capabilities of the United States have been more than adequate, and a major concern has been to deal with crop surpluses. Except during the war years agricultural production continually exceeded the rate of consumption. However, factors of stress on future production are now becoming apparent and indicate an approaching era of food scarcity.

WORLD POPULATION PROBLEM

Three hundred years ago the world population consisted of approximately 600 million people. Since that time there has been an explosive rate of population increase. (See Figure 1). In 1798 Malthus (1) hypothesized that food supply would ultimately determine population number. Population decimation effects of famine, war, and infant mortality have been modified by application of medical knowledge, birth control, migration, and transportation to determine the present population distribution. At the present rate of increase, Asia with an annual increase of 24 million, by 1980 will have a population equal to the present world population. Forty-seven million persons are added to world numbers each year. According to data presented by United Nations (2), the world population of 2,737 millions will be doubled in the next 40 years. Latin America now has the fastest growing population in the world with an annual increase of 2.5 percent against the rate of 1.7 in the United States and 1.6 percent increase for the world as a whole.

Disease control programs have allowed the population of Ceylon to double in less than 20 years. Japan has more than half as many people as the United States contained in an area the size of the State of Montana. There are 5.5 people per arable acre in Japan, as against 0.3 persons per acre in the U.S. In over-populated India half the population die before reaching the age of 13 and give an average life expectancy of 32. It is estimated that half of the 90,000,000 babies expected to be born in 1958 face a world of famine and starvation.

POPULATION TRENDS IN UNITED STATES

While world population is rapidly increasing, similar trends are evident in the United States. (Figure 2) There are twice as many

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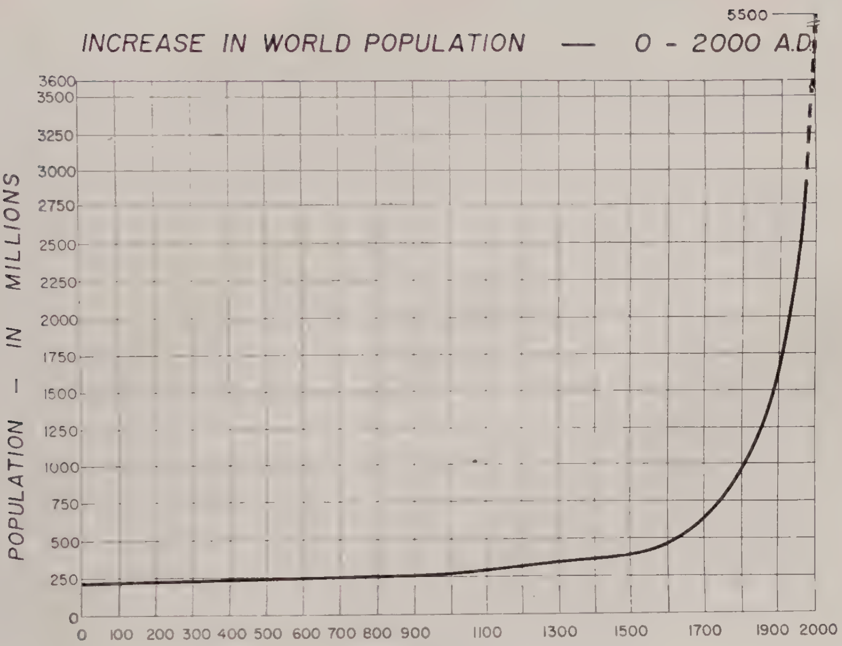

Figure 1.

people in this country as there were fifty years ago. Approximately three million persons are now being added to our country annually. In 1800 90% of our population of 4,000,000 lived on farms and were largely contained in the original 13 states. By 1870 with a population of 40,000,000 people, this farm percentage had decreased to 50%. Only twenty years ago 25% were still on farms. Today about 12% live on farms, but in the meantime our total population has risen to about 175 million (4). By 1980 we anticipate over 250 million people in this country. (The Census Bureau has projected this figure to a possible 272 millions, according to a recent press release.)

INCREASE IN FARM MECHANIZATION

The number of work animals in this country reached its peak soon after 1915 as shown in Figure 3. At that time farm mechanization had increased man's productive capacity so that one farm worker produced the food and fiber requirements for seven people. Tractors were just being introduced for agricultural use. Each farm tractor replaced about 4½ horses and mules. By 1955 the number of tractors surpassed the number of work animals. One American farm worker now produces food and fiber for 25 persons. We have less than seven million farm workers in a country of 175 million! In Russia one farm worker today supplies the needs of himself and 2½ other persons. This level of Russian efficiency is equal to that attained in this country about 1820. Today, through mechanization, each Illinois

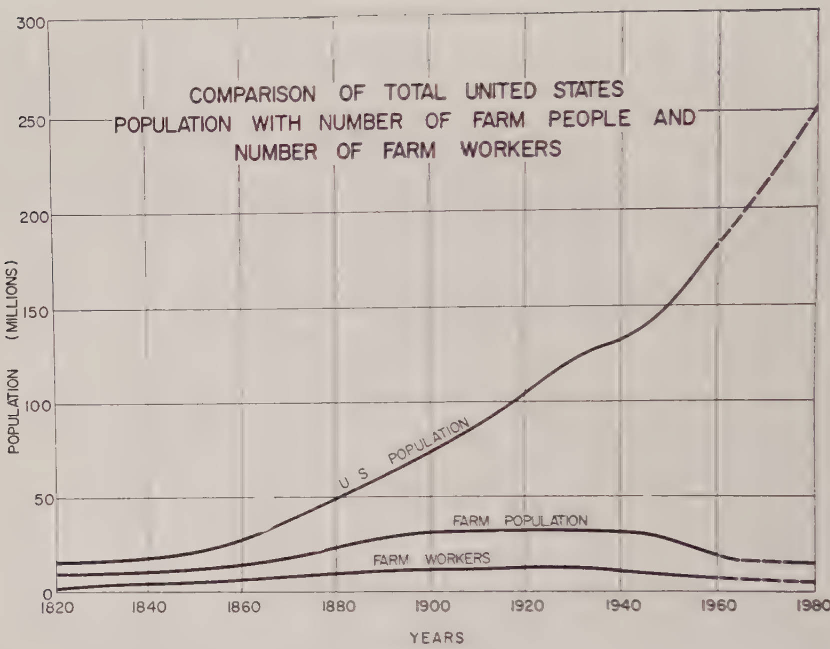

Figure 2.

farmer produces four times as much corn as a farmer in 1910. Total output of farm produce per man-hour in the United States has nearly tripled since 1940 compared to an increase of only 40% in industry during the same period.

With farm mechanization the farmers' needs from urban industry have increased. Just before World War II only 25 percent of the farm production supplies came from urban-industry. Today about 60 percent of these needs are so obtained, and by 1975 it is anticipated that 75 percent of the farmer's production supplies will come from urban sources. The American farmer uses 6,600,000 tons of steel in a year's operations. This is more steel than is used in the entire automobile industry. The farmer spends, in addition, three billion dollars for maintenance supplies and uses 17½ billion gallons of gas and oil annually.

REDUCTION IN AVAILABLE CROP ACREAGE

With the increasing rate in farm mechanization and subsequent replacement of work animals with farm tractors, the increase in United States' population was fed from acres previously given to production of horse feeds (see Figure 4). A 40-year low in crop production acreage was reached in 1957 with one-third billion acres. At the present time we have ten percent less cropping acreage than in 1930. The per capita crop acreage has decreased from 2.15 acres in 1930 to about 1.78 acres in 1955—a reduction of 27%. Highway construction, urban development, airports, etc. are further diverting ap-

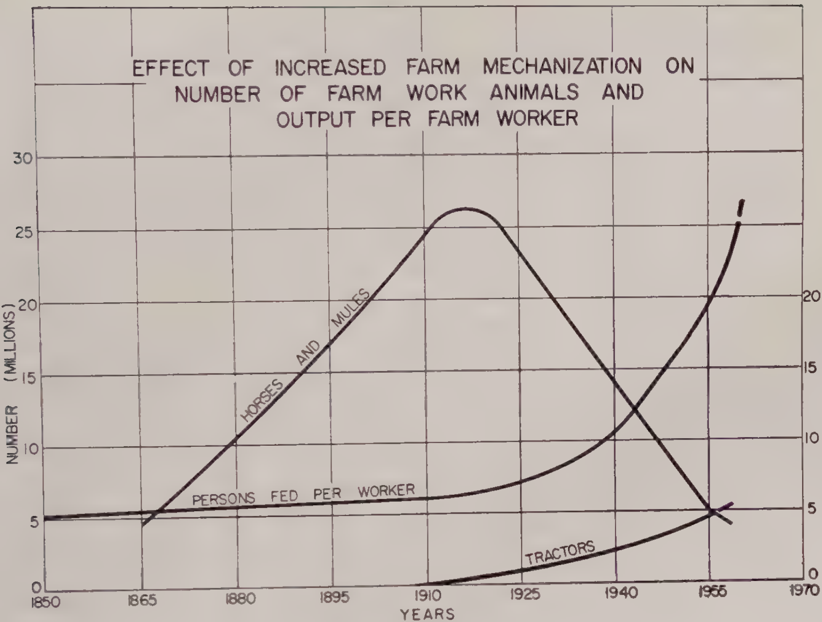

Figure 3.

proximately 1,250,000 acres each year away from crop use. Destruction of soils by erosion at the estimated rate of 400,000 acres annually is also decreasing the amount of land available for crop use. In 1917, 91,000,000 acres of crop land were used in the production of feed for work animals. Forty years later less than 8,000,000 acres were used for such purposes. Acreage from which crops are exported has, except during the depression of the 1930's remained quite constant. With increasing demands all over the world we cannot expect many of those export acres to become available for domestic use. It is significant that 58% of the 1956-57 wheat crop was exported after a 40-year decline in U.S. per capita wheat consumption of 43%. Per capita consumption of potatoes in this country during the same period showed a reduction of 45%. Attempts to maintain price levels of these specific products in the face of declining per capita consumption have resulted in accumulated storage of surpluses.

AVERAGE YIELDS OF U.S. CROPS

With increasing population, fewer farmers, fewer acres and little hope of diverting acreage to use for domestic consumption, we, as agronomists, are prone to look to higher yields per acre as a means of solution of the food problem. As shown in Figure 5, in the 90-year period (1865-1955) wheat yields increased 44%, corn yields 45%, oat yields 19% and hay yields 19%. Population during the same period increased more than 350%. Acreage for these above four crops constitutes about 75% of the total crop acreage in the U.S.

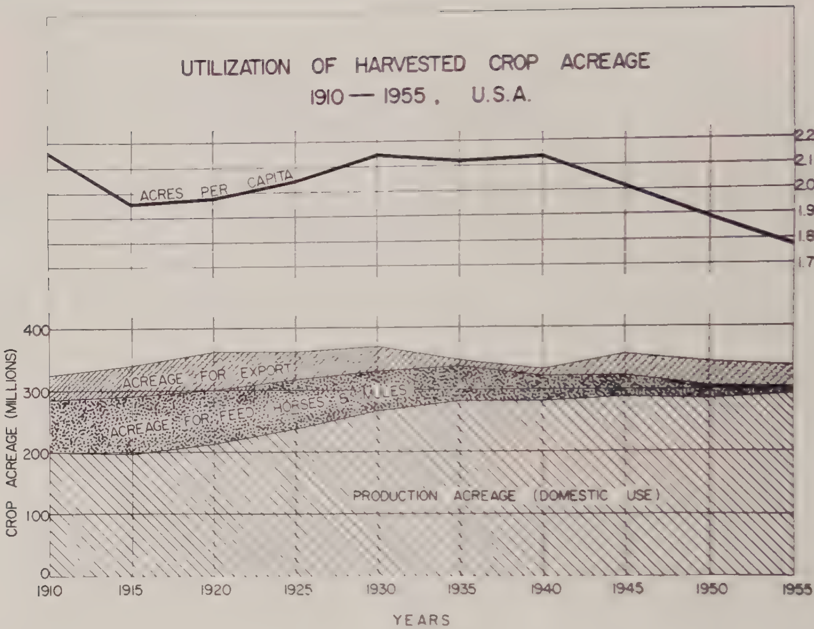

Figure 4.

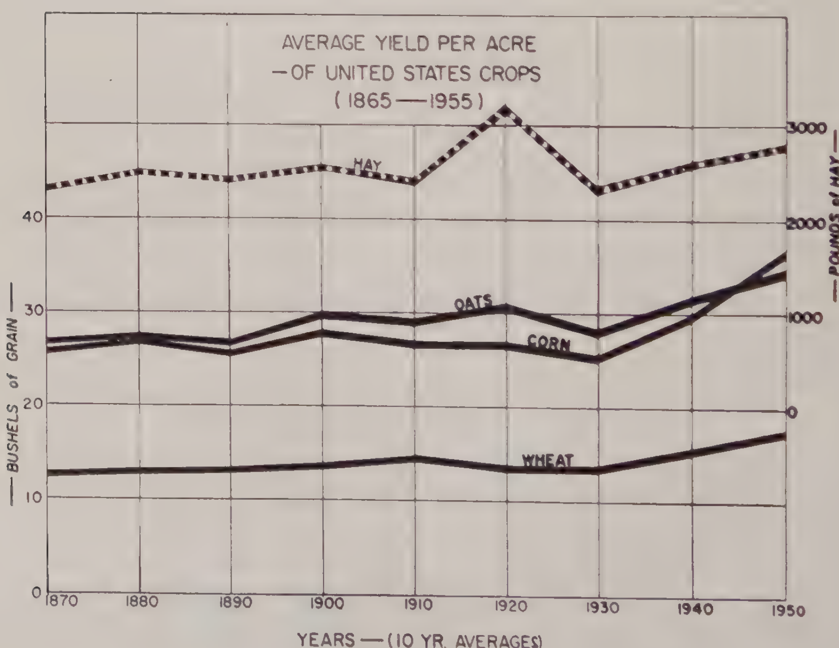

Figure 5.

Breeding of improved crop varieties, better cultural methods, higher quantity fertilizer usage, and improved insecticides and fungicides, have been sufficient to counteract increased ravages of disease and insect pests and to compensate for an ever-decreasing state of natural soil fertility. In very recent years we have had a cycle of years of favorable weather conditions for growing crops. A prolonged drought, such as occurred in the middle 1930's would greatly reduce the apparent production gain which has been obtained.

FUTURE OUTLOOK

In looking ahead to 1975 we foresee an increase of over 55 million people in the United States. There will be approximately 28,000,000 fewer crop acres. Higher per capita incomes of 50-60% will create demands for one-third more livestock for human consumption. It seems apparent that a critical situation might exist in the United States by 1975 with respect to the present standards of food consumption. This condition no doubt will be greatly influenced by the world economy. Approximately 90% (3) of the arable land in China is now planted to crops used directly for human food. In the United States over 50% of the food energy of the diet is derived from animal sources, i.e., meat, milk, and eggs. These animal derived foods call to mind the relative inefficiency of animals in producing human food. Beef cattle are rated approximately 5% efficient in human food production while hogs have an efficiency rating of 20%. That is, twenty acres of crops fed to cattle would produce the same amount of human food energy as one acre from which grains or vegetables were eaten directly by humans. Eventually, to cope with increasing population on fewer acres it may be necessary to alter the food habits of the American people. In the more populous countries, of which many are already primarily on vegetable or grain diets, the only answer appears to be control of population numbers. Japan is now advocating birth control to counteract the effects of Marshall Plan medicine. Communist Asia has recently offered payments to individuals submitting to sterilization. America deserves a better fate!

Today nine billion dollars a year are spent for research and development in this country. This figure, while very small in comparison to a national personal income of some 340 billions of dollars, is larger than all the research expenditure between 1776 and World War II.

These conditions taken together call for an efficient high level of production from our farms and conservation of all our agricultural resources. Prices must increase as the pendulum swings from its apparent present state of overproduction to a prospective future of agricultural scarcity. Our present habits of living "high-on-the-hog" will be curtailed from eating beefsteak to the direct utilization of more efficiently-produced foods.

Farm mechanization, better fertilization practice, new pesticides, improved crop varieties, and better management have all contributed to a revolution in agriculture. The degree to which further technical

advances can produce higher crop yields and more efficient use of animal feeds will determine how long our present standards of food consumption can be maintained.

REFERENCES

1. Malthus, Thomas R. An Essay on the Principle of Population (1798; reprinted by Macmillan, London, 1926)
2. Determinants and Consequents of Population Trends. U.N. Population Studies No. 17 (United Nations, New York. 1953)
3. Leonard, Warren H. World Population in Relation to Potential Food Supply. Scientific Monthly 85:113-125. 1957.
4. Agricultural Statistics 1957. United States Dept. of Agriculture. Government Printing Office. Washington, D. C. 1958.

Difficulties in Soil Sampling St. Augustinegrass Pastures on Everglades Organic Soils*

Albert E. Kretschmer, Jr.**

Soil testing of Everglades organic soils has proved beneficial as an aid for recommending the amounts of P and K necessary for maximum growth of various vegetable crops (1). Although similar analyses have been made for these soils under pasturage, little is known of their effectiveness in predicting mineral requirements of the grass.

The problems presented in sampling pastures on mineral soils in Florida have been discussed by Pritchett and others in 1953 (6). Organic soils have the ability to retain more P and K per given volume than mineral soils. Also, the stocking rate with cattle is much higher than that on the mineral soils. These two factors complicate the sampling problem. It was believed at the outset of these experiments that these factors would result in much greater variations of soil P and K from one area in the pasture to another; and that the overall pasture might be described in a three-dimensional manner with a horizontal flat surface representing the true average content of P or K and various cones of different diameters and heights protruding in both directions in a random manner representing high or low concentrations of the elements.

The data presented in this paper confirm the above description and show that an erratic distribution of P, K, and Na was found in soils from representative Roselawn St. Augustinegrass pastures.

As a background note, it should be mentioned that at the time of this work it was believed that Roselawn St. Augustinegrass would respond to additions of P and K, if soil test results for these elements showed values of less than 5 and 80 pounds per acre, respectively.

EXPERIMENTAL

All soil samples were collected, using a one inch diameter sampling tube, to a depth of 3 or 6 inches. The chemical procedures were similar to those described by Forsee and Ozaki (2), and consisted of using a volume measure of screened, air-dry soil, and extracting K and Na with 0.5 *N* acetic acid; distilled water was used to extract P. Statistical analyses were based upon procedures used by Patterson (5) and additional help was obtained from Sasso and Umana.[1]

When sampling, special care was taken to avoid obvious urine and manure deposits in the pastures.

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[1]The author is indebted to Roberto Sasso, Director of the Institute of Statistics and to Rodrigo Umaha, Professor of Statistics, University of Costa Rica, San Jose, for their helpful suggestions.

PROCEDURES AND RESULTS

1. *Ranchers' Samples*—Results of P and K analyses of service samples sent by ranchers to the Everglades Station in 1954 were examined. The author went to each of 6 Roselawn St. Augustinegrass pastures chosen at random, and obtained 12 separate 0 to 6-inch soil samples. Each sample was a composite of 2 cores obtained as close together as practical (about 1 inch apart). Each of the twelve was analyzed for P and K, and a simple average was obtained. These data are presented in Table 1. The size of the pastures varied from 20 to 80 acres.

Although less than one month had elapsed between the ranchers' and the Everglades Station sampling, it was obvious that large differences in soil P and K contents existed between areas in the same field. Furthermore, there was little similarity between soil test results of ranchers' samples and average values obtained from samples taken by the Author.

2. *Soil Variations of P, K, and Na from Samples Collected Close Together and Far Apart in the Same Pasture. Variation Due to Laboratory Technique*—A simple experiment was initiated to determine whether the large variation within a heavily grazed pasture resulted from non-reproducible laboratory methods or from actual variations in the field.

Forty 0 to 6-inch soil samples were obtained at random from a pasture for K, Na, and P analysis. There were 20 pairs of samples, each pair taken more than 50 feet apart from the other (sites). The distance between samples of the same pair was about one inch. Duplicate chemical analyses were made from each sample (total of 80 determinations for each element). Differences among chemical analyses of the same core, among cores (pairs), and among sites were determined.

Figure 1 shows that the differences between sites were extremely large for all elements. The ranges in P, K, and Na contents were 4.2 to 14.6, 42 to 603, and 30 to 283 pounds per acre, respectively. Averages were 6.5, 123, and 88 pounds, respectively.

The estimated standard errors for duplicate chemical analyses of the same sample, for cores at the same site, and for sites were calculated.[2] For P, K, and Na standard errors of 1.1, 3.7, and 4.0 pounds per acre, respectively, were found for laboratory analyses. Among cores the standard errors were 0.4, 76.7, and 17.7 pounds per acre for P, K, and Na, respectively. When tested to determine if these values were significantly different from zero, the standard errors for K and Na were highly significant while the one for P was not significant. Standard errors for sites were 2.2, 142.0, and 62.2 pounds per acre for P, K, and Na, respectively. These values were all highly significant.

These results clearly indicate that variations due to laboratory techniques were very small compared to variations in K and Na found among sites. The effects of the large between-site variation became

[2]Calculated under the direction of Senores Sasso and Umana, loc. cit.

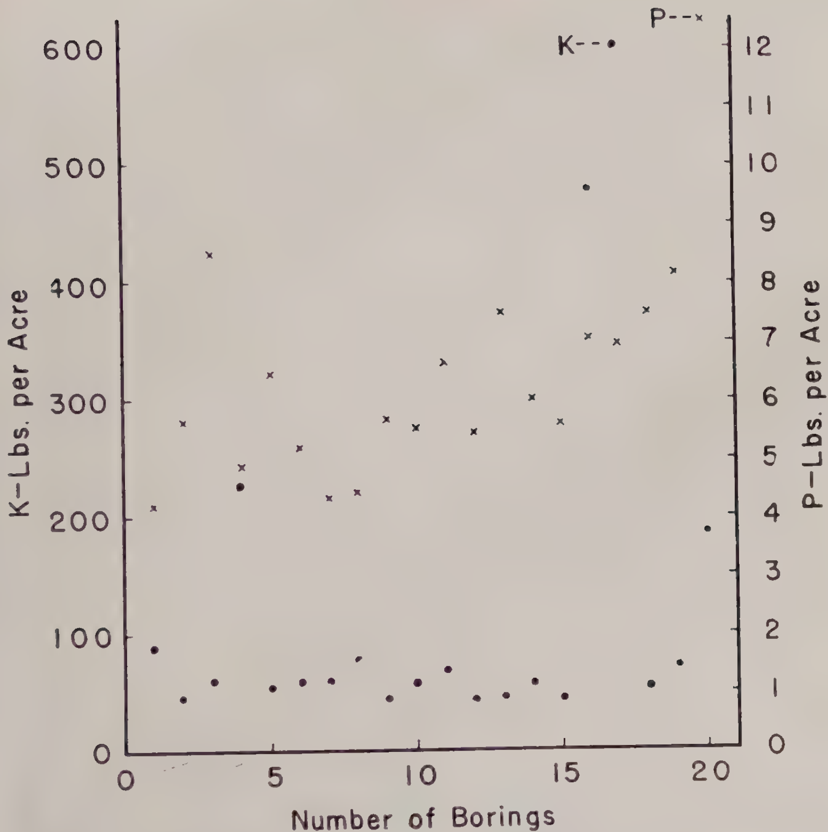

Figure 1.—Soil P and K contents obtained from twenty sites in a Roselawn St. Augustinegrass Pasture on Everglades peaty muck soil.

more apparent for K when it was found that the average K content of 123 pounds per acre obtained from the 20 sites did not present a clear picture of the K status of the soil. Fifteen of the 20 sites had K contents of less than 80 pounds per acre, the value below which K fertilization would be recommended. The relatively high average resulted from four samples that obviously were from urine deposition areas that could be detected only from soil test results and not by observation when the samples were taken. The soil K contents from these samples were 603, 481, 227, and 187 pounds per acre.

3. *Soil Variations Obtained From Dates, Depths, and Sites*—A comprehensive sampling experiment was conducted to evaluate further the effects of variations from one area to another. The experiment was also designed to determine variations among depths of sampling, and to answer the question "how accurately can average soil values from a pasture be duplicated when re-sampled a short time later"?

Ten Roselawn St. Augustinegrass pastures were chosen for the test areas, and each was sampled on April 6, May 5, June 9, and July 22,

1955. The pastures had been established in 1948 and 1949 and grazing was begun in 1950. Sampling consisted of obtaining 3 different and widely separated composite samples (sites), each consisting of 2 cores taken about 1 inch apart. Each core, and therefore samples from each site, was divided into depths of 0 to 3 and 3 to 6 inches. Analyses for P, K, and Na were made for all samples and simple averages were obtained for use as 0 to 6 inches samples.

Results clearly indicated that the top 3 inches contained larger P, K, and Na contents and variations among sites were large regardless of depth.

The data for 0 to 6-inch samples from the 3 sites from each of the 10 pastures on 4 dates are reported in Figure 2 in a manner that shows the difference in contents between the lowest and highest values for P, K, and Na for each of the 3 sites. This graph gives a clear picture of the maximum difference in contents that occurred among samples at any given date. Each bar, from left to right for each pasture, indicates maximum differences found among the 3 sites obtained April 6, May 5, June 9, and July 22, respectively. Two horizontal lines were drawn, the lower representing an arbitrary limit above which differences might be expected to be of practical significance when making fertilizer recommendations for P and K. The values chosen were 20 pounds per acre for K and Na and 2 pounds for P. The upper horizontal lines represent values twice as great as those of the lower lines.

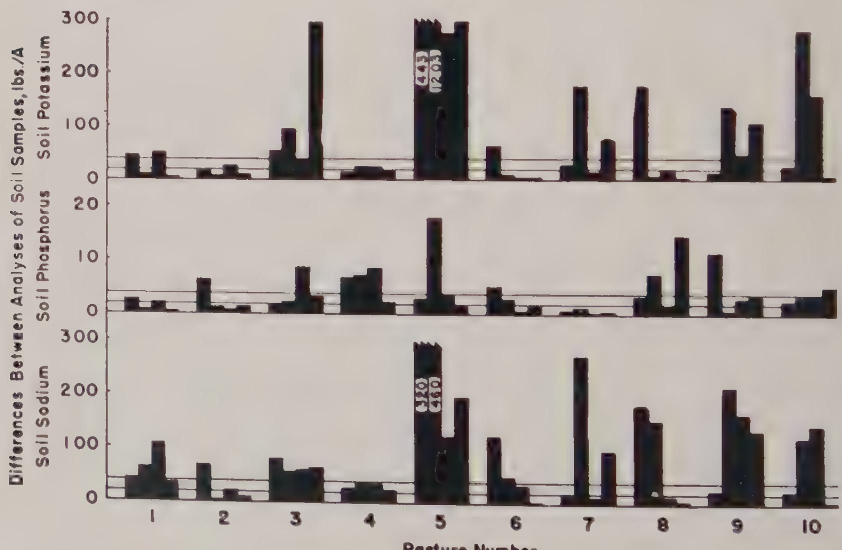

Figure 2.—Differences between the lowest and highest content of P, K, and Na found in three soil samples taken at each of four sampling dates from 10 different Roselawn St. Augustinegrass pastures. From the base lines to the center horizontal lines represent differences of 20 pounds per acre of K and Na, and 2 pounds per acre of P. The upper lines represent differences of twice those of the center line. For each pasture, from left to right, sampling dates were April 5, May 6, June 9, and July 22, 1955.

ABLE 1.—Comparison of P and K Analyses of Soils from Roselawn St. Augustinegrass Pastures Collected by Ranchers and by Experiment Station Personnel.

ture	Phosphorus - lbs/A			Potassium - lbs/A		
		Experiment Station*			Experiment Station*	
	Rancher	Average	Range	Rancher	Average	Range
	13	6	4-11	120	39	17-142
	7	5	3-19	300	71	24-278
	5	5	3- 7	130	83	15-301
	10	18	14-33	70	152	82-255
	7	8	7-17	65	183	38-744
	11	7	4-11	263	58	47-82

*Ranchers' samples received less than one month preceding sampling by Experi-
nt Station.

For example, if analyses for K of the 0 to 6-inch samples from 3 es for the April 6 sampling of pasture 1 were 30, 40, and 80 pounds r acre, the difference, 50 pounds would be plotted on the graph. the 40 differences for K, 24 were higher than 20 pounds, and 18 re higher than 40 pounds per acre. For P, 24 of the 40 calculated ferences were larger than 2, and 11 were greater than 4 pounds per e. It was even more surprising to find that 11 differences among tes of sampling for K were larger than 100 pounds per acre and 9 ferences in P contents were more than 6 pounds per acre. These ults indicated that even in a composite soil sample composed of 10 res, 2 cores would contain at least 100 pounds more K than the core ntaining the lowest K value.

Additional information on the difficulty of obtaining consistent soil t results from the same pasture if samples are taken at different tes is shown in Figure 3. There the average P, K, and Na contents 0 to 6-inch composite samples (average of 3 sites) are plotted. For stance, average soil K contents for pasture 1 were 89, 41, 57, and 36 unds per acre for the April 6, May 5, June 9, and July 22 sampling tes, respectively. Differences were calculated for each pasture, i.e. -36 equals 53 pounds per acre. In only one of the pastures was the ference in K contents less than 20 pounds per acre, 2 less than 40, d there were 7 having differences greater than 50 pounds per acre. other words, it was only possible to obtain consistent results within 50-pound limit for 3 of the 10 pastures. For P, 3 pastures had dif- ences less than 2, and 5 had differences more than 4 pounds per re. In 8 of the 10 pastures, Na contents were more than 40 pounds r acre.

It was surprising to find, on the other hand, that the differences r P and K, among the lowest contents of the three samples for a ven pasture from one date to another were rather small. In only of the 10 pastures were K differences larger than 30 pounds and P ore than 3 pounds per acre.

Potassium deficiency Symptoms of St.Augustinegrass—The possi- lity of utilizing visual symptoms of deficiencies as a basis of fertilizer

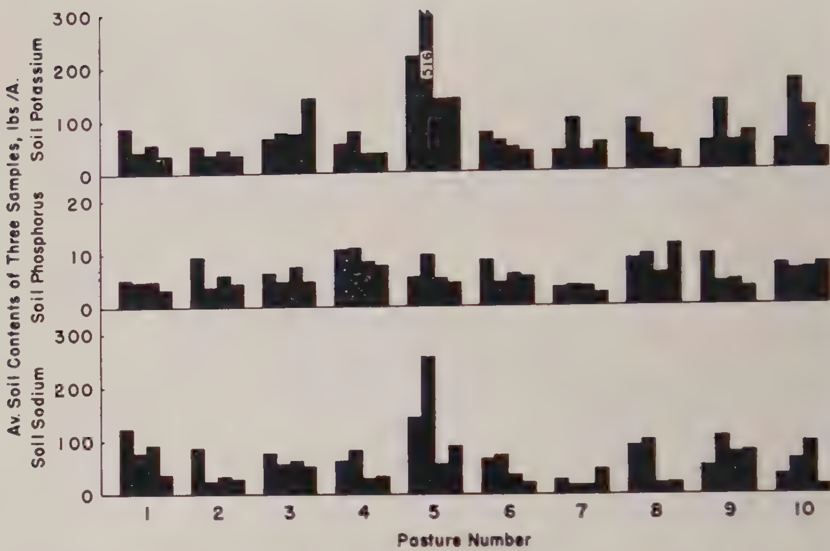

Figure 3.—Average soil contents of P, K, and Na, from three sites in each picture. From left to right for each pasture, bars represent sampling on April 6, May 5, June 9, and July 22.

recommendations should not be overlooked. Sodium requirements are unknown, but it is doubtful that additions of this element would be practical. Although the author has not observed a P deficiency of St. Augustinegrass, he has been told that such a condition does exist. The purple coloration sometimes observed on leaves is usually considered a result of N deficiency and, or, cold weather.

On the other hand, during periods of optimum growing conditions with adequate N, P, and minor element supply, K deficiency symptoms are easily recognizable and widespread. In areas of pastures that are low in K, symptoms cannot be seen year-round, but only during the spring and summer when conditions are optimum for growth. Never has the author observed an entire pasture that has manifested these symptoms. Generally, the affected areas were more or less circular and less than 10 feet in diameter (although they may be found overlapping each other); the incidence of these affected areas in the whole pasture could be classified from light to heavy. All the Roselawn St. Augustinegrass pastures observed in the spring and summer of 1954 and 1955 contained at least a few of these areas.

Grass obtained from affected areas contained from 0.14 to 0.95 per cent of K, while those from areas that appeared normal contained 1.06 to 2.34 per cent. Correction of the symptoms by soil additions of K takes about two weeks provided enough rainfall occurs.

A picture and description of a rather severe K deficiency is shown in Figure 4. It should not be confused with the rice disease, *Piricularia oryzae,* as previously described (3, 4).

On May 5, 1955, the percent of K deficient areas were estimated in 6 of the pastures that were used for the soil testing experiment. Pas-

Figure 4.—Physiological disturbances of Roselawn St. Augustinegrass that results from potassium deficiency. The brown small round to rather large elongate areas, sometimes irregular, appear first on the older leaf blades, but under conditions of severe deficiency can be found on all but the youngest blade. There are no ashen-gray center areas within the brown areas.

tures numbered 5, 6, 7, 8, 9, and 10 were estimated to have 10, 50, 30, 50, 10, and 10 per cent K deficient areas, respectively. It was obvious that differences in the severity or numbers of deficient areas existed among some of the pastures, and although the estimates may not have been very precise, the relative differences were believed fairly accurate.

DISCUSSION

The basic problem of sampling organic soils (and possibly other pasture soils that are heavily stocked and that resist leaching) is not whether a representative sample can be obtained, since this problem can be more or less solved by taking a large number of samples in a given area. The real question is whether the fertilizer recommendations based on soil tests can serve a useful purpose. If we assume that a sample can be obtained that represents the average content in the whole pasture, and this assumption was neither proved nor disproved by the work presented, many times recommendations would be against the use of fertilization even though 10 to 50 or more per cent of the pasture actually might be deficient. This inconsistency is a result of the extremely high levels of P and K that "build up" in certain areas from continued excreta from grazing animals. It was shown that the soil nutrient variation within a pasture was extremely

large and that it was difficult to obtain similar results from consecutive samplings of the same pasture. These results question the validity of sampling these soils in a manner similar to that recommended for pastures in other states and on the mineral soils of Florida. These are all based upon the assumption that a more or less representative sample will be obtained that is valuable for recommending or not recommending fertilizer when the chemical analyses are completed.

Another possibility is to base the fertilizer recommendation upon the lowest level of a given nutrient obtained from separate chemical analyses of an arbitrarily chosen number of individual borings from pastures. With this system the deficient areas in the pastures would have an adequate quantity of nutrients. The disadvantage would be that in many instances an expensive application of fertilizer would benefit only a small part of the whole pasture. Also, the cost of soil analyses would be increased. It appeared from results of the experiment in which 10 pastures were sampled at 4 different dates that there was much more consistency from one date to the next if the lowest soil test value of the three samples was used throughout rather than the average value.

Another and possibly most convenient method for basing fertilizer recommendations, but only for K, is the visual approach. By observing a St. Augustinegrass pasture in the spring it would be possible to estimate the per cent of deficient areas that existed and to fertilize with K if stocking rates and economic conditions warranted. It is more difficult to detect K deficiency symptoms on other grasses used in this area, but possibly a more careful examination of the leaves would provide a similar means for estimating the extent of the deficiency.

When it is known at what levels for P and K a fertilizer response may be anticipated, possibly a combination of methods, including the use of tissue testing, can be used upon which to base recommendations. Until more accurate sampling methods are devised, testing organic soils under pasturage has a limited application except under special conditions.

CONCLUSIONS

1. Soils contents of P, K, and Na were extremely variable from one area in a pasture to another. Variations resulting from laboratory chemical techniques were small from a practical standpoint.

2. It was difficult to obtain consistent soil test results for P, K, and Na from the same pasture sampled on different dates.

3. The top 3 inches of soil consistently contained larger quantities of P, K, and Na than did the 3 to 6-inch zone.

4. It is suggested that for recommendations of K fertilizers on St. Augustinegrass pastures, visual K deficiency symptoms would provide the most logical method of approach.

REFERENCES

1. Forsee, Jr., W. T. 1953. Utilizing soil tests as a basis for the determination of optimum levels of phosphate and potash for crops growing on Everglades peat and muck soils. Soil Sci. Soc. Fla. Proc. 81: 124-130.

2. ——————, and Ozaki, Charles T. 1954. Rapid laboratory methods for the analysis of soil and plant tissue samples. Everglades Station Mimeo Report 55-6.

3. Green, Victor E., Jr. 1958. Observations on fungus diseases of rice in Florida 1951-1957. Plant Disease Reporter 42 (5): 624-628.

4. Kretschmer, Albert E., Jr. 1954. Florida Agr. Exp. Sta. Ann. Rep., pp. 204-205.

5. Patterson, D. D. 1939. Statistical Technique in Agricultural Research. McGraw-Hill Book Co. New York.

6. Pritchett, W. L., Breland, H. L., and Hanson, W. D. 1953. Sampling soils on a field basis. Soil Sci. Soc. Fla. Proc. 8: 131-141.

Aluminum Studies on Some North and Central Florida Soils

J. G. A. Fiskell, C. C. Hortenstine,
H. L. Carver, and H. W. Lundy*

The first indication that aluminum may be high in plants grown in the North and Central Florida was the work reported in 1945 by Robinson and Edgington (9) who found the leaves of the sweet leaf, *Symplocos tinctoria* from the Gainesville area contained from 4 to 5 times as much aluminum as calcium or potassium. In the same area, hickory leaves contained 1.3 per cent alumina on a dry weight basis. Recently, Fiskell and Robertson (3) obtained data showing that the aluminum in potato leaves was much higher where the yields were lowest than where better yields and larger sized tubers were found on Kanapaha fine sand. Fiskell and co-workers (1) also reported that aluminum occupied a major part of exchange complex in several soils from this area. The pH of such soils was above 5.0 with less than 10 per cent of the exchange capacity accounted for by calcium, magnesium and potash. Earlier, the work of Gammon *et al* (4) indicated that these latter cations accounted for only a small fraction of the exchange capacity throughout profiles of 33 different soil types from this part of Florida.

Most of the soils are quite sandy and many large areas are very low in organic matter. Since optimum moisture is often not present the crops may suffer some drought damage. Poor root systems are usually found where yields are commonly low. Very low rates of fertilization are often used and liming is not practiced by many farmers. At the Suwannee Valley Experiment Station, response to lime on Klej fine sand was obtained for peanuts each year over a 4-year period (8). In this area dolomite was more effective than high calcic limestone because magnesium was too low in the soil. After an application of finely ground limestone in 1957, a very great yield increase was obtained for corn over adjacent plots which were unlimed but received the same fertilization.

This paper presents further evidence of the aluminum status of several soils.

EXPERIMENTAL

Both soil and plant analysis were used in the study of the aluminum status of some North and Central Florida soils and crops. Soil analysis for exchangeable cations and phosphate was made using normal ammonium acetate at pH 4.8 as the extracting solution. For

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sandy soils 25 grams and for peats 10 grams of sieved, mixed soil was shaken with 200 ml. of this reagent for one hour and filtered. For aluminum, 10 ml. of the leachate was used with aluminon buffer and hydroxylamine reagent, adjusting the volume to 45 ml. and the pH to 3.7 by the glass electrode, and boiling briefly to obtain maximum color development. The color was read at 530 mu. using the Beckman D. spectrophotometer and standard curves used for the calculation. Plant analysis for aluminum was made similarly using a suitable aliquot of the ash of 10 grams of dry plant material taken up in normal hydrochloric acid. Calcium, potassium and sodium analysis for the soil were by the flame photometer and the same for potassium in the acid solution of the plant ash. Calcium, in solutions of plant ash, was determined by double precipitation as the oxalate after iron and aluminum was removed as hydroxide and phosphate precipitated at pH 6.0. Magnesium was determined by the thiazole yellow method stabilized by polyacrylate. Manganese was determined by the periodate procedure for permanganate development. Iron was determined using O-phenanthroline at pH 4.0. Phosphorus value was obtained using the standard stannous chloride and sulfomolybdate method. The soil pH was measured in water and in N potassium chloride solution using 1 : 2 soil to solution ratio. After filtration, the latter solution was titrated using 0.1 N sodium hydroxide and phenolphthalein indicator. The aluminum and titrateable hydrogen were determined in Klej fine sand using 4 N calcium chloride as extractant, shaking for one hour with a 1:8 ratio of soil to solution.

Cation exchange capacity at pH 4.8 and 7.0 was determined by leaching the soil several times with normal ammonium acetate at the desired pH. This was followed by several complete leachings with neutral normal potassium chloride. Then, excess salts were removed by several rinsings with ethyl alcohol. Finally, the ammonium ion was leached from the soil by N hydrochloric acid and determined by the standard Kjeldahl distillation into boric acid.

In a detailed study of Klej fine sand, each soil sample was obtained by shaking the soil from 10 corn plants pulled up by the roots for each plot. For soybean plant analysis, the upper leaves from 10 or more plants were sampled per plot and treatment.

RESULTS AND DISCUSSION

The soil analysis of several soil types and their location are given in Table 1. To emphasize the amount of aluminum extracted to that of other elements in the same extract, the ratios of these elements to aluminum are shown. This system also makes it easier to compare the analysis of one soil type with another. It is also possible that this may be representative of the situation encountered by feeder roots.

1. *Soil pH.* The pH of each soil type at the several sites in Table 1. is lower where potassium chloride is used instead of water. The exchangeable hydrogen ion concentration determined with the potassium chloride reagent using fluoride in the method of Yuan (11) was in no case greater than 0.03 milliequivalents per 100 grams of soil. There was little difference in this value between soil types even on Brighton

TABLE I.—Aluminum in Several Soil Types in North and Central Florida with Related Data on Soil pH, Exchange Capacity and Ratios of Other Cations to Aluminum Extracted by Normal Ammonium Acetate at pH 4.8.

Soil Type	Depth	Site	County	Al	pH H_2O	pH KCl	C.E.C. pH 4.8	C.E.C. pH 7.0	Ca/Al	Mg/Al	K/Al	Mn/Al	Fe/Al	P/Al
	in.			ppm										
Klej f.s.	0-6	1	Suwannee	41	6.03	4.99	2.42	4.45	2.1	0.67	0.32	0.05	0.12	0.24
	0-6	2	"	46	5.80	4.72	2.33	4.98	1.3	.78	.33	0.03	0.12	.27
Bushnell l.f.s.	0-4	1	Lafayette	5	5.63	4.40	5.30	6.72	50.0	26.00	2.40	1.20	2.30	.64
Blanton f.s.	0-5	1	"	9	6.08	4.60			19.3	8.30	1.60	.12	.76	.91
Jonesville-	0-6	1	Alachua	38	5.70	4.62	3.09	3.76		1.08		.15	.18	.32
Hernando		2	"	31	5.65	4.52	4.76	8.00	8.5	.27	.51	.05	.17	.30
f.s. complex		3	"	51	6.20	5.08	6.09	7.78	5.8	1.15	3.12	.01	.13	.28
(limed)		4	"	29	6.05	4.83	4.11	6.10	10.2	1.30	1.85	.08	.13	.38
		5	"	68	5.95	4.78	5.43	------	5.3	1.04	.59	.02	.06	.19
		6	"	87	5.90	4.70	------	------	2.0	.43	.92	.04	.04	.12
		7	"	120	6.00	4.99	4.45	7.65	2.4	.34	.67	.01	.04	.06
Lynchburg	0-4	1	Washington	221	5.05	4.10	------	------	------	.09	.54	.02	.48	
l.f.s. (virgin)	4-9	1	"	210	4.90	4.15				.02	.08	.01	.34	
Immokalee	0-6	1	Hardee	6	5.20	4.72			118.0	11.3	35.5	.52	1.10	1.00
f.s. (limed)		2	"	6	5.68	5.30	------	------	102.0	22.4	35.0	.67	1.33	6.70
		3	"	6	5.83	5.35	------	------	185.0	22.2	40.0	.37	1.28	6.50
		4	"	6	5.06	4.55	------	------	236.0	12.0	24.6	.31	1.13	3.42
		5	"	17	5.83	5.45	------	------	76.0	8.0	24.2	.27	.38	3.24
Brighton peat	0-8	1	Putnam	216	3.60	2.88			3.5	1.1	1.0	.01	.78	.29
Everglades	0-6	1	Orange	44	5.35	5.28			93.2	5.5	1.1	.08	.12	.18
peat		2	"	56	5.32	5.24	------	------	109.0	22.8	3.7	.09	.05	
		3	"	28	5.51	5.24	------	------	153.0	34.8	7.9	.15	.03	.74
		4	"	15	5.85	5.75			259.0	66.3	38.6	.09	.13	1.67

peat. The increased acidity between the two methods for the pH measurement indicates the degree of soil hydrolysis. For aluminum this equation is

$$Al^{+++} + 3H_2O = Al(OH)_3 + 3H^+ \qquad (1).$$

In the presence of chloride, aluminum hydrolysis in pure chemical solutions gives pH 4.0. Possibly manganese and iron might also produce hydrogen ion hydrolysis but these are usually present in the extract in very much less quantity than is aluminum. Soil pH is defined by the senior author as the ability of a soil to produce hydrogen ions by hydrolysis and this effect is proportional to the soluble salt concentration present. Russell (10) has reviewed recent thinking on the subject of pH and hydrolysis.

As the anion concentration in the soil, particularly after fertilization, is decreased by heavy rains the soil capacity for hydrolysis should decrease. The equilibrium state will approach that indicated by pH determination in freshly distilled water. Many areas using high rates of fertilizer have shown a higher pH after the summer rains. The soils studied, Table 1, all were sampled either after the heavy period of rainfall in the spring of 1958 or in September of the same year following the wet weather in August. With anion depletion, bicarbonate salts of cations being released from the exchange complex should dominate the soil solution which would then be more alkaline in nature. However, if the soil complex released aluminum then acidity might develop as shown in Equation 1. Referring back to Table 1, the virgin Lynchburg loamy fine sand and the very acid Brighton peat were the most acidic in water and in potassium chloride solution and these soils had by far the highest aluminum extracted by ammonium acetate. The problem of interpreting the pH of these soils in terms of aluminum and hydrogen would require more research, since the aluminum extracted by potassium chloride is much less than with the ammonium acetate reagent at pH 4.8. These data might serve as a way the problem could be attacked.

2. *Cation Exchange Capacity.* The several comparisons of the cation exchange capacity at pH 4.8 and 7.0 (Table 1), show that the former is about one-half the latter. There is some indication however, that this difference is narrowed where the soil calcium is much higher than the aluminum extracted. This decrease in exchange capacity with pH is basic to the problem of leaching in Florida sands. Several workers have shown an increase in exchangeable hydrogen as the soil pH is made neutral or more alkaline (10). Yuan and Fiskell (12) found that aluminum extracted with ammonium acetate is less as the pH is raised from 4.8 to 7.0 or above.

Since the minimum solubility of aluminum hydroxide is at pH 6.5 (6), the increase in hydrogen, the decrease in aluminum and the increase in exchange capacity fit into a chemical pattern. The senior author proposes the following reactions may occur on the cation exchange complex to explain this pattern as the pH is increased which means more hydroxide ions are provided:

Firstly, aluminum ion changes to the hydroxide form on the exchange as the pH is increased. Secondly, the aluminum hydroxide being amphoteric in nature assumes properties of aluminate. The

aluminate then has two free hydrogens and one hydrogen bonding or oxygen linkage with the exchange site. Thus two hydrogens in exchangeable form are created for each aluminum originally on the exchange site. This sequence can be compared to the following chemical reactions,

$$Al^{+++} + {}_3OH^{-} = Al(OH)_3 \quad (2)$$
$$Al(OH)_3 = H_3AlO_3 \quad (3)$$
$$H_3AlO_3 = AlO_3^{---} + {}_3H^{+} \quad (4)$$

except that each aluminum uses a bond to the exchange site. Since aluminum hydroxide has maximum insolubility at pH 6.5, aluminum ions at this pH should be converted to the hydroxide state without necessarily being removed from the exchange site. If the ammonium or other cation exchange with the hydrogen of the aluminate is complete at pH 7.0 or above then this will be included in the cation exchange estimation. Therefore, exchange capacity at 7.0 is increased over that at pH 4.8 because for each exchange site retaining the aluminum or other hydroxide forming element two hydrogens may be split from their oxygen bonding. This postulation has not been presented previously and requires further research.

3. *Relationship of Aluminum to Other Cations and Phosphate.* The samples of Klej fine sand, Jonesville—Hernando fine sand complex, Lynchburg fine sand and Brighton peat were lower in calcium aluminum ratio than the virgin Bushnell loamy fine sand, Blanton fine sand, Everglades peat or the limed Immokalee fine sand. The magnesium aluminum ratios showed a similar difference to calcium between soil types. Manganese aluminum ratios were highest for the Bushnell loamy fine sand and Immokalee fine sand. These two soil types and Brighton peat have the highest iron aluminum ratios. The phosphorus aluminum ratios were very low for the Lynchburg loamy fine sand, Jonesville fine sand and Klej fine sand. The meaning of these ratios is not yet known. However, the Immokalee fine sand with high ratios produces excellent pasture and other crops at the Range Cattle Station and the Everglades peat in the Zellwood area, also with very high ratios, is one of the most fertile soils. Soils with the low ratios such as Klej fine sand and Jonesville fine sand do not produce good yields unless limed and fertilized well.

4. *Effect of Dolomite Applications on Aluminum in Klej Fine Sand.* In Table 2 are shown analysis of aluminum, magnesium and phosphorus in Klej fine sand at 5 rates of dolomite application. The aluminum extracted by acid ammonium acetate decreased with level of dolomite applied. The change in exchangeable magnesium is shown in relation to the aluminum, increasing from one-eighth to two and one-half times the aluminum extracted. When acid ammonium fluoride (strong Bray reagent) was used, aluminum extracted was 12 to 20 times greater than with acetate and both aluminum, and aluminum to phosphorus ratio, increased slightly as liming rate increased. This might be evidence of aluminum hydroxide increase as the liming rates increased. Yield responses were reported previously (8).

TABLE 2.—Effect of Dolomite Applications Applied to Klej Fine Sand on Soil Al and Al/Mg Ratio Extracted by Acid Ammonium Acetate and on Al and Al/P Ratio Extracted by 0.03N NH_4F in 0.1N HCl.

Dolomite tons/acre	Soil pH	Ammonium acetate, pH 4.8		Ammonium fluoride	
		Al	Al/Mg ratio	Al	Al/P ratio
		ppm		ppm	
0	5.63	99	8.20	1200	6.1
½	5.84	89	3.60	1230	6.7
1	5.98	86	2.30	1380	6.0
1½	6.50	82	0.89	1420	7.9
2	6.80	76	0.39	1530	9.9

5. *Effect of Hydrated Lime on Corn Yields.* With magnesium requirement known to be a factor on Klej fine sand (8), this experiment was used to determine the effect of liming on corn yields with uniform fertilization containing 2 per cent magnesium oxide. The area grew very poor soybeans the year previous and at that time had received differential zinc treatments. Three replicates received 1000 lbs. of hydrated lime per acre and two were unlimed. The yield data are shown in Table 3. The yield response to zinc was not significant and this has been confirmed in minor element studies with a nearby experiment over a period of years (7,8). However, the response to lime was 22 bushels.

The soil analysis for the respective corn yields are shown in Table 4. Examination of these data showed little change in pH or calcium by the liming indicating that the lime was likely leached. The soil calcium levels on the unlimed soil were much higher than those reported for another area (8). The magnesium levels were about the same at all yields. Differences in the potassium, sodium, manganese, iron and phosphate values were not in relation to yield differences. The yield differences were most striking on the west side of the experiment. Here the lowest yields on the unlimed soil were adjacent to the highest yields on the limed soil. The number of stalks were alike but

TABLE 3.—Yield of Dixie 18 Corn Grown on Zinc-Lime Study at the Suwannee Valley Experiment Station, 1958, with Fertilizer Containing Magnesium Sulfate Applied Uniformly.

Treatment	Limed	Unlimed	Difference
lbs. zinc/acre	bu./a	bu./a	bu./a
None	59.9	43.1	16.8
2.4 row	58.1	31.3	28.8
7.2 row	55.2	42.0	13.2
21.6 row	56.4	40.0	16.4
21.6 broadcast	60.0	26.5	33.5
9.6 row chelate form)	59.9	33.7	26.2
Average	58.3	36.1	22.2**

**Highly significant increase for lime but not for zinc treatments.

TABLE 4.—ANALYSIS OF SOIL IN ROOT ZONES AND YIELDS OF DIXIE 18 CORN GROWN IN KLEJ FINE SAND WITH AND WITHOUT HYDRATED LIME.[1]

Yield, bushels per acre	pH		Al ,ppm		Parts per million Acid ammonium acetate extractable						
	water	N KCl	NH_4Ac	$CaCl_2$	Ca	Mg	K	Na	Mn	Fe	P
Soil unlimed in 1958											
8.6	7.02	5.68	88.2	2.11	240	29	134	20	1.2	5.2	15.0
18.3	6.72	5.25	50.8	2.20	198	37	175	40	1.3	6.7	15.2
22.1	6.82	5.45	42.5	2.11	134	33	126	32	12.4	7.1	7.8
25.2	6.60	5.35	35.8	1.18	288	31	76	24	1.2	4.4	9.3
37.4	6.60	5.40	39.2	1.96	269	29	189	25	5.5	7.3	16.3
42.4	6.68	5.68	29.6	1.70	298	26	35	34	4.1	3.6	12.0
49.0	6.60	5.55	24.8	1.46	158	14	22	15	1.2	5.4	9.7
57.8	6.57	5.39	26.6	.84	202	25	101	13	2.2	4.6	12.8
Soil received hydrated lime, ½ ton per acre											
43.1	6.85	5.55	41.3	1.18	370	27	127	32	1.2	4.4	9.3
48.5	7.00	5.50	31.7	1.02	192	34	251	18	5.5	7.3	16.3
54.3	6.83	5.45	30.0	.88	213	41	182	21	1.3	5.6	12.0
55.7	6.98	5.62	29.6	.85	260	32	141	19	4.2	5.2	16.0
56.7	6.85	5.96	27.0	.96	278	29	77	19	5.0	5.0	12.0
58.2	6.58	5.40	37.6	....	253	36	124	30	2.2	5.9	8.3
60.4	7.00	5.80	31.1	1.14	346	29	86	32	4.1	4.2	14.4
60.2	6.50	5.38	28.2	1.12	269	27	117	17	2.4	8.3	14.7
61.5	6.93	5.50	28.8	.32	240	21	147	20	1.2	5.4	16.0
62.0	7.40	6.05	33.6	.34	510	31	193	16	1.2	5.4	9.7
64.0	6.80	5.45	34.2	.68	192	26	122	14	5.0	4.4	15.2
68.1	7.55	6.45	34.8	.43	480	34	120	17	5.5	5.8	19.2

[1]Received uniform rate of fertilizer, 600 lbs of 4-8-8 containing 2% MgO and side-dressed with 100 lbs. of ammonium nitrate.

the number of ears was less on the unlimed soil with stunted, spindly stalks and poor root systems. Corn ears were not fully filled on the poorest plots. Since calcium and magnesium in the soil was as high in these root zones as where yields were 2 or 3 times greater, some other soil factor must have been the limiting one. This was the case as shown in the next section.

6. *Relationship of Soil Aluminum to Corn Yields.* The regression relationship of acetate extractable aluminum on corn yields was found to be highly significant with a 't' value of 4.66. The linear regression function is

$$Y = 80.7 - 0.91\ Al_1 \qquad (5)$$

where Y is the expected yield and Al_1 the parts per million of aluminum found. This is shown in Figure 1. Where less than 35 ppm. of aluminum were present yields of 55 bushels were obtained but at 88 ppm. of this element only 8.6 bushels was found. When aluminum was determined by extraction with calcium chloride, the linear re-

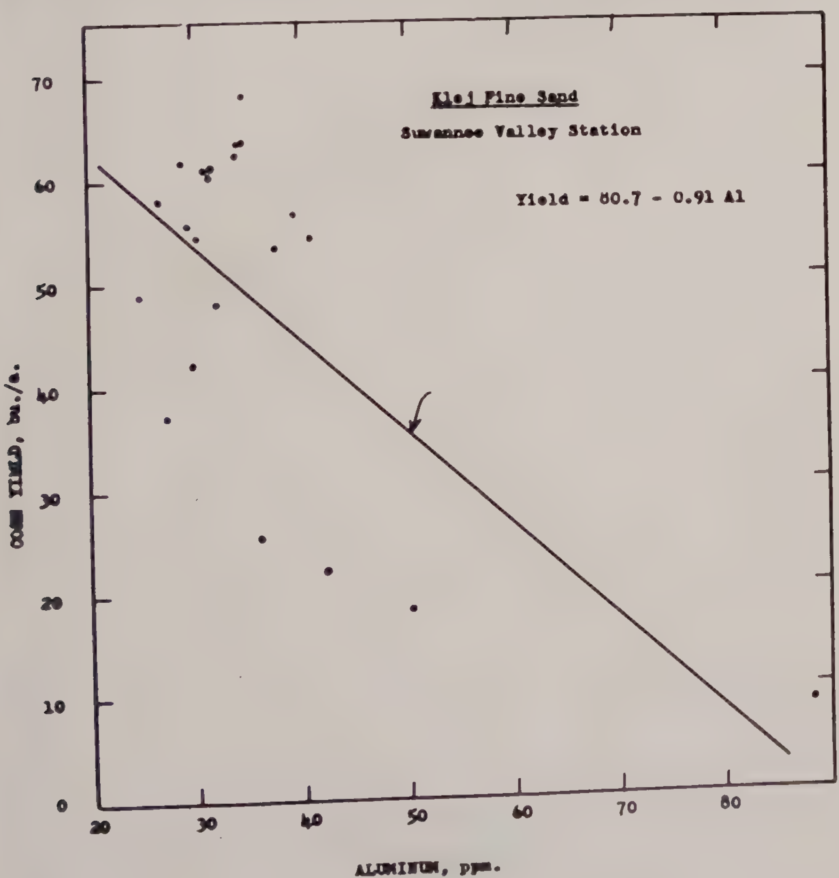

Figure 1.

gression function was also highly significant (t -13.7). The expression is

$$Y=76.6-25Al_2 \qquad (6)$$

where Y is the expected yield and Al_2 the aluminum found by extraction with calcium chloride reagent. This relationship is shown in Figure 2. The low values obtained by this method require a large aliquot of the leachate, usually 25 ml., for accuracy. The relationship of calcium to aluminum ratio was also found to be a very significant (t=3.86) linear regression function. This equation is

$$Y=19.0+3.6\ Ca/Al \qquad (7)$$

where Y is the yield expected and Ca/Al the ratio of these elements found by extraction with acid ammonium acetate. The regression relationship is plotted in Figure 3. The 't' value is less for Equation 7 than 5 which is expected since calcium was not a significant regression factor on yields. Significant regression relationship of alum-

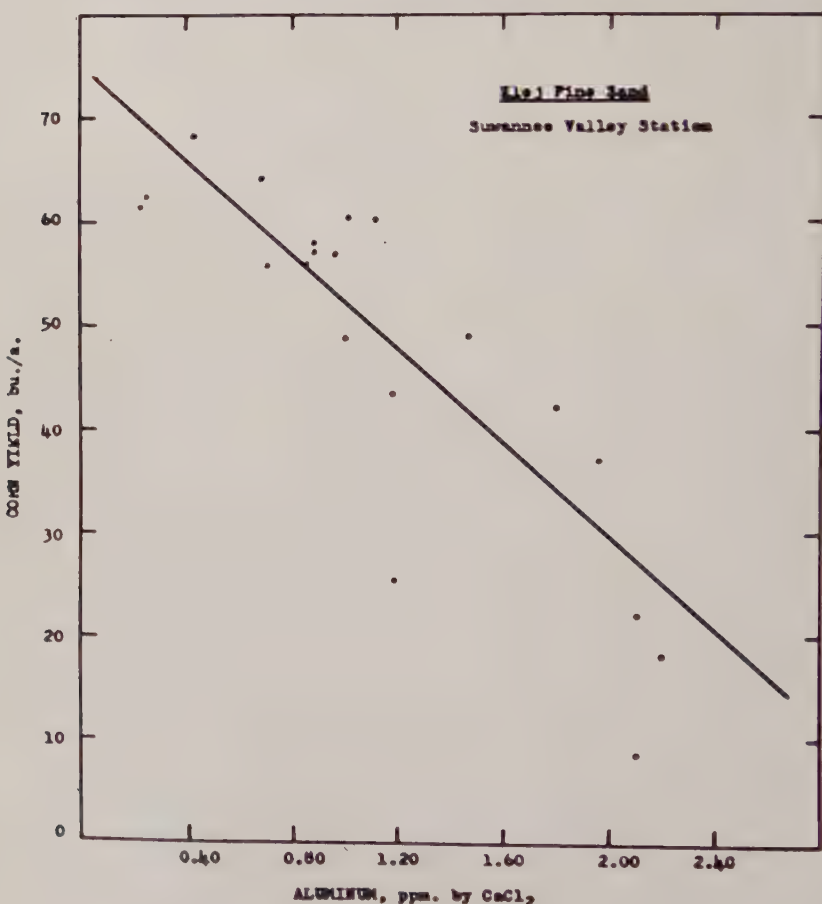

Figure 2.

inum and calcium rates on corn yields has been found for several soils in separate experiments at the West Florida Station (2,5).

7. *Leaf Analysis of Soybeans, Corn and Peanuts Grown on Klej Fine Sand.* In 1957 growth of soybeans on Klej fine sand in the above area and on a nearby fertility trial was very poor. Plants were stunted with small, chlorotic leaves apparently magnesium deficient. On the poorest areas leaves were falling off. Leaf samples were taken from both areas and the data for leaf analysis and yields are given in Table 5. In these leaves, the calcium was moderately low. The magnesium content confirmed this deficiency diagnosis from the leaf chlorosis. Potassium is likely adequate. Iron levels were probably sufficient. Note, however, that very high aluminum and manganese content were found in the leaves from unlimed soil which was pH 4.7. The liming with a ton of high calcic limestone applied in 1954 and an additional ton of dolomite before planting, decreased greatly the aluminum and manganese content. The leaves on the limed plots were larger and chlorosis was much less severe than those on the un-

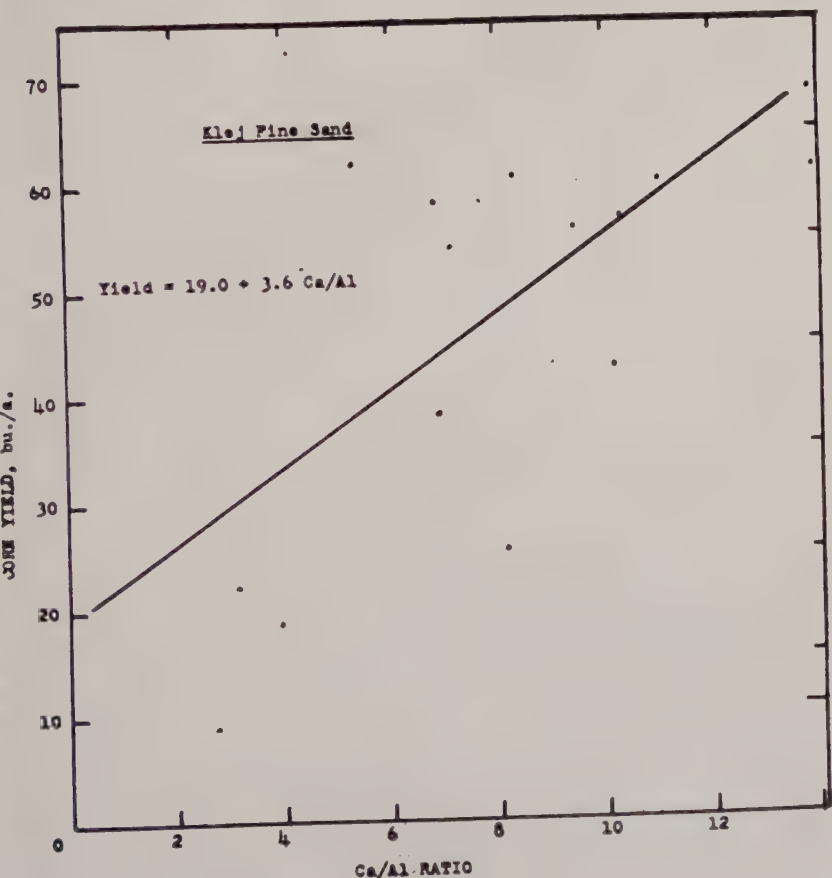

Figure 3.

TABLE 5.—YIELD AND COMPOSITION OF SOYBEANS GROWN ON KLEJ FINE SAND IN FERTILITY TRIALS AT THE SUWANNEE VALLEY STATION IN 1957.

Treatment[1]		Yield	Leaf composition at flowering, mean of 2 replicates					
			Ca	Mg	K	Al	Mn	Fe
		bu./a	%	%	%	ppm	ppm	ppm
$N_0P_0K_0$	U	0.3	1.25	0.12	1.36	940	3320	185
	L	5.7	1.14	.16	1.78	1150	1440	74
$N_0P_3K_3$	U	3.4	1.15	.11	2.00	1050	3320	37
	L	6.4	1.38	.07	1.50	275	1010	97
$N_1P_3K_3$	U	2.5	1.58	.06	2.87	525	4800	94
	LL	8.2	1.17	.12	2.96	350	1120	67
$N_2P_3K_3$	U	2.6	1.38	.11	1.79	790	2140	65
	L	3.9	1.16	.07	1.52	250	600	44
$N_3P_3K_3$	U	4.1	1.25	.13	1.96	775	1400	107
	L	3.7	1.36	.08	2.44	750	1200	160
$N_3P_0K_3$	U	0.8	.91	.09	2.59	950	2850	81
	L	7.0	1.24	.11	2.36	420	620	55
$N_3P_1K_3$	U	1.1	1.24	.05	2.04	960	3860	70
	L	5.4	1.77	.15	2.16	400	1230	36
$N_3P_2K_3$	U	1.6	1.28	.06	2.34	775	1330	35
	L	6.6	1.85	.19	1.94	530	660	29
$N_3P_3K_0$	U	1.9	1.95	.11	1.23	750	3100	38
	L	3.3	2.16	.16	1.34	350	650	37
$N_3P_3K_1$	U	1.4	1.56	.06	1.57	1240	5200	60
	L	6.4	1.74	.14	1.60	465	1310	42
$N_3P_3K_2$	U	1.7	1.08	.05	2.01	1760	3930	39
	L	6.2	1.48	.16	1.66	385	1300	77

[1]Rates of nitrogen as N are 0=0, 1=5 lbs., 2=10 lbs., 3=15 lbs.
Rates of phosphate as P_2O_5 are 0=O, 1=25 lbs., 2=50 lbs., 3=75 lbs.
Rates of potash as K_2O are 0=0, 1=25 lbs., 2=30 lbs., 3=45 lbs.
Lime, 1 ton per acre in 1956.

limed plots. The phosphorus may have had some effect on the aluminum but the variability was great. The manganese content was high at all fertility rates. The accumulation of aluminum and manganese could have occured because magnesium was insufficient since it has been generally accepted that the total bases approaches a constant in a particular plant species.

In Table 6, the aluminum content is shown for corn and peanuts on limed and unlimed Klej fine sand. The aluminum content was decreased by liming. The soybeans sampled in this case which were rated as excellent both in plant vigor, number of pods and freedom from chlorosis showed lower aluminum in leaves, pods and washed roots than other soybean plants in the same field showing slight chlorosis.

TABLE 6.—Aluminum Content of Soybeans, Corn and Peanut Plant Tissues Grown on Klej Fine Sand at the Suwannee Valley Station.

Plant Tissue	Aluminum, ppm Al Limed	Unlimed	Decreased by liming
Peanuts plants	70	110	40**
Corn ear leaves	49	84	35**
Soybeans, excellent			
Leaves	35		
Pods	8		
Roots	80		
Soybeans, good but less vigorous			
Leaves	67		
Pods	22		
Roots	69		

**Seven paired comparisons highly significant difference by "Student's" t test.

CONCLUSION

The soils of North and Central Florida apparently have appreciable exchangeable aluminum. This affects the pH, and the exchange capacity in ways not yet proven. However, the postulated mechanisms are presented to encourage further research on these subjects. The ratios of other elements to exchangeable aluminum are likely to prove useful in defining the level of tolerance for these in sandy soils. Since the regression relationship of aluminum extracted and corn yields was highly significant using both acid ammonium acetate and calcium chloride reagents, the need for keeping aluminum in balance with other elements is shown. Where an element such as magnesium is in too low a supply, aluminum may be taken up in very large amounts. From all evidence to date, aluminum in the soil and in the plant is a common and natural event and fertility is related to the aluminum availability.

LITERATURE CITED

1. Fiskell, J. G. A., Gammon N. Jr., Yuan, T. L., and Zmeskal, O. Colloidal properties of some Florida soils. Soil Sci. Soc. Amer. Proc. 22:339-343 (1958).
2. Fiskell, J. G. A., and Hutton, C. E., Aluminum as a soil fertility factor for corn grown on Norfolk fine sandy loam. Soil Sci. Soc. Amer. Proc. (manuscript).
3. Fiskell, J. G. A. and Robertson, W. K. Comparison of broadcast and row fertilization for potatoes on Kanapaha fine sand. Fla. Sta. Hort. Proc. 70: 96-103. (1957).
4. Gammon, H. Jr., Henderson, J. R., Carrigan, R. A., Caldwell, R. E., Leighty, R. G., and Smith, F. B. Physical, spectrographic and chemical analysis of some virgin Florida soils. Fla. Agr. Exp. Sta. Tech. Bull. 524. pp. 74-99. (1953).
5. Hutton, C. E., Fiskell, J. G. A., and Lutrick, L. C. Effects of phosphate additions on acetate extractable aluminum in two West Florida soils and on corn yields. Soil and Crop Sci. Soc. Fla. Proceedings. (This issue).
6. Kolthoff, I. M. and Sandell, E. B. Textbook of Quantitative Inorganic Analysis. The MacMillan Company, N. Y. pp. 324-327. (1945).

7. Lundy, H. W. Soil management investigations. Fla. Agr. Expt. Sta. Annual Rept. pp. 360. (1957).

8. Robertson, W. K., Hutton, C. E., Lundy, H. W., Thompson, L. G. and Lipscomb, R. W. Effect of lime on some North Florida soils. Soil & Crop Sci. Soc. Fla. Proc. 17: 72-85. (1957).

9. Robinson, W. O. and Edgington, G. Minor elements in plants, and some accumulator plants. Soil Sci. 60: 15-28. (1945).

10. Russell, Sir. E. J. Soil Conditions and Plant Growth. Eighth Edition. Longmans, Green and Co., London. (1950).

11. Yuan, T. L. Determination of exchangeable hydrogen in soils by a titration method. Soil Sci. (In press).

12. Yuan, T. L. and Fiskell, J. G. A. Aluminum studies II. The extraction of aluminum from some Florida soils. Soil Sci. Soc. Amer. Proc. (In press).

Water Table Fluctuations in Sandy Soils at Hastings, Florida

DONALD L. MYHRE[1]

INTRODUCTION

The "water table" is defined as the locus of points in the soil-water system at which the water has atmospheric pressure (5). It is the upper limit of the saturated soil, and varies with the amount of precipitation and irrigation. Periods of high precipitation cause the water table to rise, whereas dry periods generally cause it to decline.

The location of the water table is important from the standpoint of irrigation and drainage of "flatwood soils" in Florida. A permanently shallow water table exists in the sandy soils used for vegetable production in the Hastings area, which makes it possible to use the furrow method of sub-irrigation. Water is introduced into the soil profile by running it into trapezoidal furrows which run parallel with the potato rows. These furrows are about 18 inches deep, 12 inches wide at the bottom and 42 inches wide at the top, and are usually spaced every 16 rows or 60 feet. Lateral and downward movement of water from the furrows raises the water table, which is normally located less than four feet below the top of the ridged row. Dikes are used in the furrows to maintain the water table at the desired level. The water moves upward by capillarity into the root zone from the water table.

The purpose of this paper is to describe the characteristic fluctuations of the water table as measured in pipes installed in sandy soils at several locations.

EXPERIMENTAL PROCEDURE

Water table measurements were made across two 16-row beds (120 feet) which were part of a furrow sub-irrigation experiment during the 1958 potato growing season (3). Sixteen holes, each about six inches in diameter and three feet deep, were made in the center of ridged potato rows with a post-hole digger. The tops of the ridged rows were about 12 inches above the bottoms of the alleys between rows. An aluminum pipe three inches in diameter, three feet long, and containing 50 small holes in the lower one foot, was installed in each hole. Soil was placed around the pipe and pressed firmly around it. The top of each pipe was 5.9 feet above mean sea level. The vertical depth from the top of the pipe, which was about level with the soil surface, to the water table in the pipe was measured daily at 4 p.m. between February 12 and April 30, and three times daily (8 a.m., 12 noon, and 4 p.m.) between May 5 and May 26.

Similar measurements were made three times daily in four pipes located across a 16-row bed between August 25 and November 10.

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However, these pipes were located in the alleys between ridged rows. The tops of these pipes were 6.3 feet above mean sea level. Also, several water table measurements were made during dry periods in the 1955 potato growing season. The depth to the water table was determined in soil auger holes about one hour after the hole was made.

A profile description of Bladen loamy fine sand (thick surface phase), in which the pipes were located, was made by Leighty et al. (2) and is given as follows:

0-8 inches, dark gray, friable loamy fine sand.

8-12 inches, dark gray with faint fine mottlings of light gray and gray, friable loamy fine sand.

12-18 inches, gray with a few fine distinct mottles of yellowish-brown and light gray, friable fine sandy loam.

18-22 inches, mottled yellowish-brown and gray, fine subangular blocky, firm, fine sandy clay.

22-42 inches, gray or light gray distinctly mottled with a few medium common areas of red and brownish-yellow, weak subangular blocky, firm fine sandy clay.

42-48 inches, gray to light gray streaked with yellowish-brown slightly friable fine sandy clay.

RESULTS AND DISCUSSION

Rainfall.—The daily distribution of rainfall during the period of this study in 1958 is given in Table 1. All measurements were recorded at 8 a.m. Monday through Friday. No records were obtained for intensity of rainfall and amount of runoff. It is estimated that at least 90 percent of the water from precipitation entered the soil.

TABLE 1.—Distribution of Rainfall Between April 13 and May 13 and September 7 and November 6, 1958 at Hastings, Florida.

Month	Day	Rainfall, Inches	Month	Day	Rainfall, Inches
April	15	0.41	Sept.	23	0.12
	16	.22		25	.02
	17	.04		26	.25
	22	.28	Oct.	2	.13
	23	.26		3	2.90
	30	.16		6	.79
May	1	.05		7	.12
	6	.75		15	.18
	7	Trace		16	.16
	12	.74		17	.21
	13	.29		20	3.27
Sept.	8	.19		31	1.12
	9	1.38	Nov.	3	.02
	12	1.39		5	1.82
	16	.27		6	.64

although the actual uptake depended on the condition of the soil and the characteristics of the storm.

Water Table Measurements.—Water table fluctuations during a part of the 1958 potato growing season, as measured in the aluminum pipes, are given in Figure 1. The sharp rise of 9.6 inches in the observed water table between April 14 and 15 was due to 0.41 inch of rainfall recorded at 8 a.m. on April 15. After the water table had reached a height of 22.2 inches in the soil profile, it gradually declined over a period of five days to a point below the 36-inch level, where it was not measurable in the pipes. This lowering of the water table was probably due to downward and lateral drainage of water and partially to the capillary rise of water which was subsequently lost through transpiration by the vigorously growing potato plants. A portion of the decline in the water table is attributed to the potato crop because it was observed that the water table declined more rapidly after rains later in the season as the plants matured. For example, on May 6 the water table was 24 inches below the soil surface as a result of 0.75 inch of rainfall, and two days later it was below 36 inches as shown in Figure 2.

Water table fluctuations in summer cover crop plots of predominantly crabgrass for the period between September 7 and November 6 are given in Figure 3. The water table was located closer to the upper soil surface during these two months than during the potato growing season because the rainfall was much heavier during the fall months. The water table rose 16 inches between September 8 and 9 as a result of 1.57 inches of rainfall. It should be pointed out that the decline was more rapid after this rainfall than after the rainfall recorded on October 20, when the crabgrass was no longer growing vigorously. The greatest rise of the water table, 25.3 inches, occurred between October 2 and 3 after 3.03 inches of rainfall.

Fluctuations of the water table due to precipitation and irrigation can be determined easily. However, it is more difficult to explain why the water table rises so abruptly after a one inch rainfall.

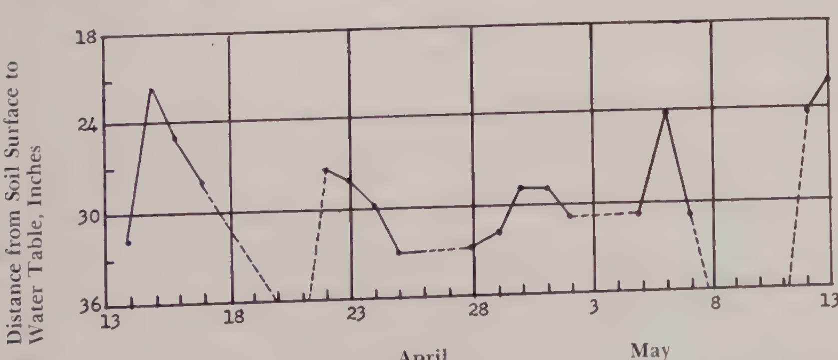

Figure 1.—Water Table Fluctuations in Potato Plots Between April 13 and May 13, 1958. Each dot represents daily measurement in pipe located in ridged row 10 feet from dainage furrow; broken line indicates days no measurements taken.

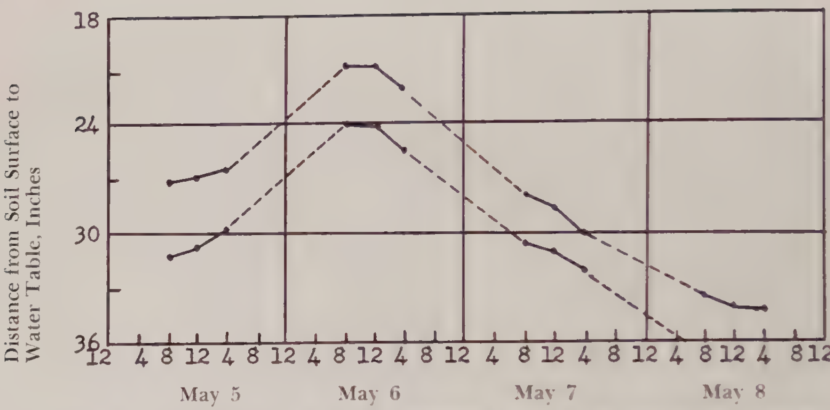

Figure 2.—Daily Changes (8 a.m., 12 noon, 4 p.m.) in Water Table Level in Potato Plots on May 5-8, 1958. Each dot in upper curve represents measurement in pipe located in ridged row 10 feet from irrigation furrow; each dot in lower curve represents measurement in pipe in ridged row located 50 feet from irrigation furrow and 10 feet from drainage furrow.

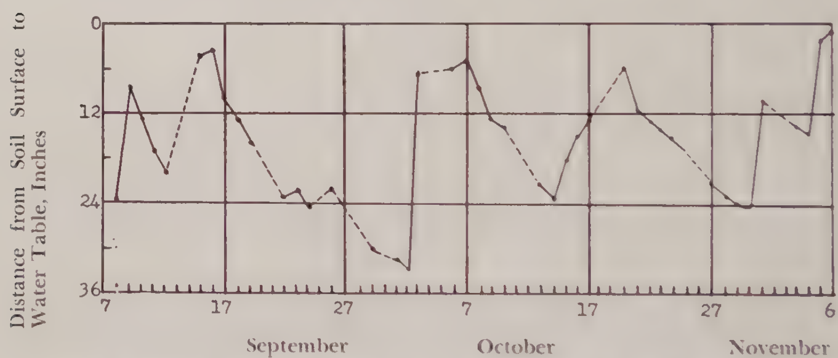

Figure 3.—Water Table Fluctuations in Summer Cover Crop Plots Between September 7 and November 6, 1958. Each dot is a mean of 3 daily measurements in 4 pipes. Broken line indicates days when no measurements were taken.

Several factors are probably responsible for this phenomenon. Water from rainfall infilters readily through permeable sands to the water table, under the influence of gravity. The pore space immediately above the initial water table may be close to saturation, so a small amount of water from rainfall may exert an appreciable effect on the observed water table 24 hours after a rainfall.

All the pore spaces may not actually be saturated below the observed water table after rains. Air may be trapped in the soil profile, and thus be partially responsible for the rise in the water table.

Water from rainfall may cause lateral movement of water above the clay under the influence of gravity to places of discharge which are reflected in a rise of the water table. This condition might be visualized as occurring in lower areas where subsurface drainage from higher adjacent areas might be occurring.

In order to obtain a better comprehension of water movement in saturated and unsaturated soils and explain why the water table fluctuates before and after rainfall, it will be necessary to make certain physical measurements in the soil profile. The total pore space and the percent occupied by water should be determined at various depths, since the proportion of solid-to-pore space varies greatly in the soil profile. Since gravity and the forces associated with a pressure gradient are the two forces that determine flow of water in a saturated or unsaturated soil (1,4,5) it also becomes necessary to determine hydraulic heads with piezometers. In addition a continuous record of water table fluctuations and precipitation should be obtained by use of automatic water level and rainfall recorders. The amount of runoff and rate of infiltration should be determined for different soils and vegetation.

CONCLUSIONS

1. In general, a one-inch rainfall resulted in an upward movement of the observed water table of 12 to 15 inches, with the magnitude of the fluctuation depending somewhat on the initial position of the water table.

2. The water table declined more rapidly when mature plants were in a vigorously growing stage than when the plants were immature or dead.

3. The introduction of water into only one furrow adjacent to a 16-row bed resulted in the water table sloping downward from the irrigation furrow to the drainage furrow during irrigation.

LITERATURE CITED

1. Baver, L. D. Soil water. Soil Physics, pp. 198-266. 1948.
2. Leighty, R. G. Classification and Correlation of the soils of Potato Investigations Laboratory, Hastings, Florida. Report June 30, 1955.
3. Myhre, D. L. Furrow sub-irrigation of potatoes. Amer. Potato Jour. 36. 1959. (In press).
4. Renfro, George M., Jr. Applying water under the surface of the ground. U.S.D.A. Yearbook of Agr., pp. 273-278. 1955.
5. Richards, L. A. Retention and transmission of water in soil. U.S.D.A. Yearbook of Agr., pp. 144-151. 1955.

Some Drainage Characteristics of a Cultivated Organic Soil in the Everglades[1]

D. S. Harrison and H. A. Weaver[2]

INTRODUCTION

One of the world's largest winter vegetable producing areas is located on the organic soils of the southern fringe of Lake Okeechobee in southern Florida. These organic deposits were not extensively cultivated and put into production until the late 1920's (3). It is now estimated that some 50 million dollars of agricultural commodities are produced annually in the Everglades.

The peat and muck soils of the Everglades area are defined by Jones et al (3) as follows: "Peat consists of 65 percent or more of plant remains, with relatively little mineral matter. Muck contains 25 to 65 percent organic matter mixed with sand, silt and clay." Peaty muck is described as a thin layer of peat over muck.

Water control has always been a problem for Everglades farmers. The elevations of the organic soils within the agricultural region are 11.5 to 13.0 feet above m.s.l. Water movement over the surface is considered poor, while water movement through the soil has been considered poor to fair (3). After extensive drainage and cultivation practices for a number of years, downward movement of soil water is generally considered to be reduced. This is especially the case after many years of cultivation wherein the organic matter content has decreased. The soil loses its fibrous nature and becomes compact as it breaks down into smaller particles.

Present research at the Everglades Station in the field of drainage has been directed toward studying the drainage characteristics of the different types of organic soils. The purpose of these studies is to determine optimum horizontal spacings of mole drains. Both field and laboratory tests on drainage rates were made. This is a progress report of one year's work on Everglades peaty muck following one year of cultivation and one year under pasture management. Two plot areas utilized for this study have been under extensive drainage for about twenty years; thus they have subsided approximately 1.3 inches per year (1). The peaty-muck, underlaid by an impermeable marl rock layer, is approximately 4 feet deep. Ground elevations range from 12.44 to 12.68 feet m. s. l. Original elevation in 1924 was approximately 16 feet m.s.l.

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[1]Cooperative research between the Florida Agricultural Experiment Station, the Soil and Water Conservation Research Division & the Agricultural Research Service, U.S.D.A., and the Central and Southern Florida Flood Control District.

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METHODS OF PROCEDURE

A. Field Observations

Two adjacent 10-acre blocks were used for field measurements. One block was sprigged with St. Augustinegrass while the other was left fallow. The plot diagram is shown in figure 1. The same system of lateral ditches served both blocks; that is, a lateral ditch bordered both the North and South borders of the two blocks.

Test No. 1. The block sprigged with grass was divided into five non-replicated treatments as follows: 1) Moled on 20-ft. spacings, 2) Non-moled, 3) Moled on 15-ft. spacings, 4) Non-moled and 5) Moled on 10-ft. spacings. Each of the three moling treatments was bordered on each side by a 100-ft buffer or non-moled area. All moles were placed at a 30-inch depth. Each treatment consisted of an area 100 feet wide by 660 feet long.

Test No. 2. The second or adjacent block consisted of four treatments as follows: 1) Check or non-moled, 2) Moled on 10-ft. spacings, 3) Moled on 20-ft. spacings and 4) Sub-soiled 24″ deep on 30-inch spacings. Each of these treatments was 60 feet wide by 660 feet long

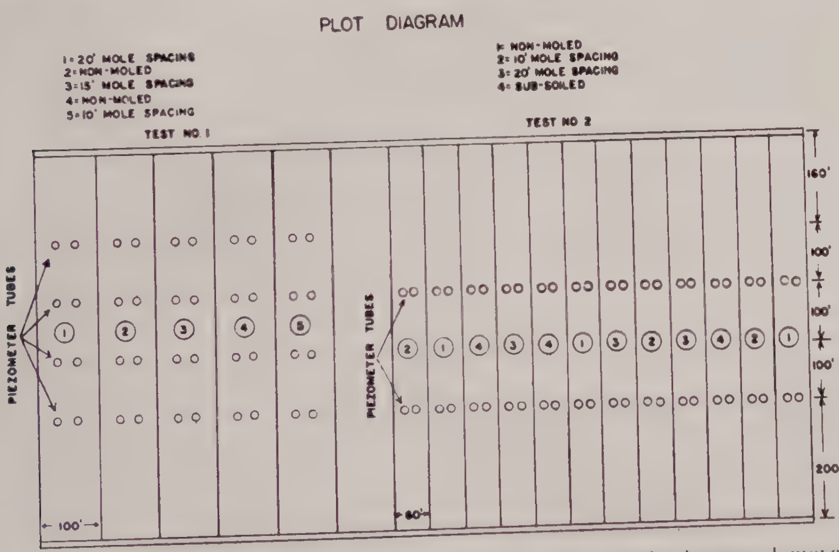

Figure 1.—Plot diagram of moling experiment used to study downward movement of water table in organic soils.

and was replicated three times. In this test only four wells (Piezometer tubes) were installed in each plot (Fig. 1). These were at the 200′ and 400-foot distances from the lateral ditch. In test 2 there were 8 wells in each plot or treatment.

Wells were made from 1½″ x 36″ galvanized pipe, attached to an 18-inch well point using a 30-mesh screen and installed to measure depth to water table. Eight wells were centrally located in each plot equidistant from drains at distances of 200, 300, 400 and 500 feet

from the lateral ditch. All wells were installed at the same elevation. After successive rains the depths to water table in each plot were measured by means of an aluminum float guage, every five hours, until drainage by pumping had ceased.

Open wells six inches in diameter, dug down to the rock layer, were installed in each of the above tests near the screened wells to serve as a check. No differences in depth to water table and rate of downward movement of soil water were noted between the two types of wells.

B. Laboratory Tests:

The saturated hydraulic conductivity of various soil layers was studied to obtain a better understanding of internal drainage characteristics. Undisturbed 3-inch diameter core samples were obtained from the 0-6, 6-12, 12-18, 18-24 and 24-48 inch soil layers.

Six sampling sites were selected at random and at each site one core was obtained from the vertical and horizontal directions at each depth. It was possible to determine statistically whether certain layers had isotropic or anisotropic flow characteristics.

The cores were prepared for test by first soaking for 72 hours and then placing in a vacuum chamber to eliminate trapped air from the pores. A hydraulic head of one inch was then applied to the upper surface of the saturated sample. After the outflow rate under this head became constant, a run of 15 minutes was made during which the percolate was collected. The saturated hydraulic conductivities were calculated from the various percolation rates. The values obtained are given in Table 1.

In addition to information on conductivity, the samples provided a means for determining the water release characteristics of the soil. This was accomplished by draining the saturated cores over water tables of various depths utilizing a sand-silt column similar to that devised by Jamison (2), but modified to permit changes in depth to water table. Since the conducting pores are largely saturated in coarse silt up to heights of three feet above water table, it was possible

TABLE 1.—Saturated Hydraulic Conductivity of Everglades Peaty Muck in the Vertical and Horizontal Directions for Various Soil Layers

Soil Depth (in.)	Saturated Hydraulic Conductivity (In./Hr.)		Flow Characteristic*
	Vertical	Horizontal	
0- 6	15.1	13.8	Isotropic
6-12	10.1	11.5	Isotropic
12-18	9.8	4.8	Unknown
18-24	16.6	3.4	Anisotropic
24-48	6.0	4.5	Unknown

L. S. D. .01 = 9.3)
0.5 = 7.0) applicable to all depths except 24-48.

*Based on statistical analyses of data from six replications. The number of replications were inadequate to ascertain the flow characteristics of the 12-18 and 24-48 inch depths.

for small samples such as those used here to drain to an equilibrium water content within a reasonable length of time after having been placed in contact with the upper surface of the column. Hence, by starting with a saturated sample, the loss in water occasioned by each successive drop in water table should give a measure of drainable water under like field conditions unadjusted for unsaturated hydraulic conductivity restrictions and evapotranspiration. Reduced unsaturated capillary conductivity retards the release of drainable water in the unsaturated zone above the water table. Evapotranspiration is also a source of water removal, so that the net water available for instantaneous underdrainage will be somewhat less in the field than that determined in the laboratory. While the error due to slow drainage cannot be assessed precisely here, the time required for water release indicated that at the higher theoretical tensions encountered above two-foot water tables (20 to 60 cm. H_2O), approximately 85 percent of the drainable water is removed in less than 24 hours. Thus, if a water table is rapidly lowered from the soil surface to a two-foot depth, approximately 15 percent of the drainable water will remain in the unsaturated profile at the end of one day. It was further indicated that this remaining water will require at least an additional seven days to completely drain down to the water table, unless first depleted by evapotranspiration. Hence, in the following discussion the calculated depths to field water tables as based on laboratory water release data are minimums.

The water released from each initially saturated three-inch soil layer in the upper 24 inches was determined for water table drops of 0 - 4 inches, 4 - 8 inches and 8 - 24 inches below the center of each

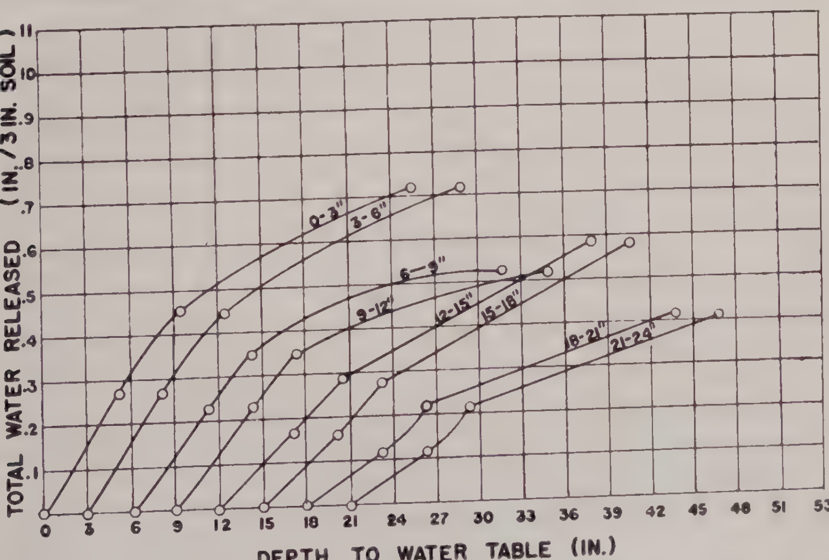

Figure 2.—Effect of water table depth on total water released from various initially saturated peaty muck layers placed in contact with a sand-silt column (curve origins shifted so that water table coincides with upper layer boundary at 0 release).

layer. The accumulated water release totals are plotted graphically in Figure 2 as a function of depth to water table in the sand-silt column.

The minimum depth to field water table may now be determined by assuming that water release is equal to underdrainage and by constructing a graph as in Figure 3. Here underdrainage required to establish a given water table in an initially saturated soil is taken as the sum of the ordinates of the points on all curves in Figure 2 directly above the value of that water table. The minimum depth to water table may then be plotted as a function of the quantity of water removed by underdrainage (Fig. 3). Such information provides a means for determining, through application of empirical formulae, maximum instantaneous drain discharge rates at specified water tables.

DISCUSSION AND RESULTS

The average depth to water table after successive rains are recorded in Tables 2 and 3 for both plot tests. The data from the non-replicated plots in test 1 revealed no differences in depth to water table in moled as compared to non-moled plots. Statistical analyses of test 2 data showed no significant differences in depths to water table among the four treatments. The accumulated time to drain for each field test was computed and the results shown in Figure 4.

Further examination of observed readings taken at 5-, 10- and 15-hour intervals after drainage began revealed that, for all practical purposes, the water table was entirely level over all the area in the field tests. Sometimes a 1-inch differential could be noted between the 200-and 500- foot distances; however, this was uniform condition for both moled and non-moled plots. This suggests that there was

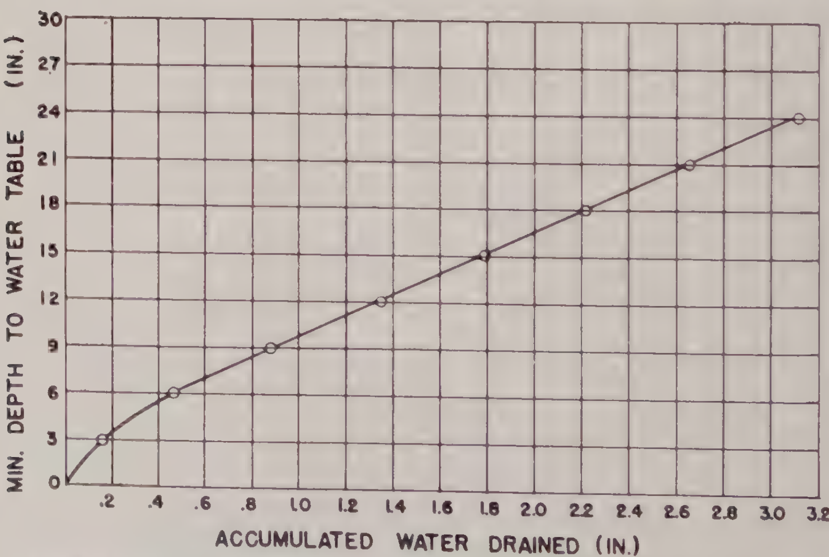

Figure 3. The relationship between accumulated water removed through underdrains and resulting minimum depths to water table—beginning with a saturated profile.

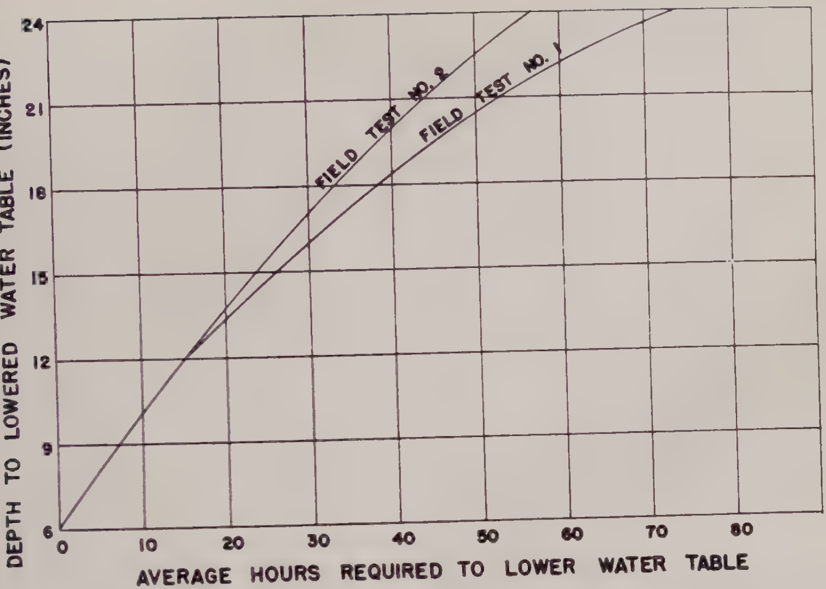

Figure 4.—Average accumulated time to obtain various water tables in field tests with initial water table at 6 inches.

some lateral drainage to both lateral ditches, even though moles were run from only one ditch and pulled out some 40 feet before they reached the other lateral ditch.

A comparison was made of actual field water table recession rates after rain and those calculated through use of a theoretical formula. The location of the field drains with respect to the impermeable layer indicated that a formula based on the assumption of combined radial and horizontal flow would fit existing conditions. Accordingly the nomographic method of Ernst and Boumans as reported by Visser (4) was employed. By selecting arbitrary values of spacing and applying the average value of horizontal hydraulic conductivity for the 12 to 48 inch layer, this method, which is normally used to determine spacings, was applied in reverse to determine instantaneous discharge rates at various water tables. Since the method was designed specifically for steady state flow (constant discharge rate and water table level), it was necessary to assume a series of steady state conditions as they varied with water table level.

In order to determine the time required to lower the water table from the upper to the lower boundary of a given soil layer, drainable water existing in and above the layer had to be divided by the instantaneous discharge rate for a water table located at the center of the layer. In this case the drainable water may be determined from Figure 3 by taking the difference between values of "water drained" for the water tables at the two boundaries of the layer concerned.

The maximum accumulated drainage time, determined above for various spacings, are shown in Figure 5 plotted against the water table level. For example, the time required to lower the water table from

TABLE 2.—Average Depths to Water Table Following Various Amounts of Rainfall, in Relation to Drainage Time, in Test No. 1.

Rainfall (inches)		Avg. depth to water table at various time (in feet)[1]									
		5	10	15	20	25	30	35	45	55	70
2.54	Field	0.40	0.66	0.81	0.90	1.03	1.15	1.24	1.40	1.57	1.70
	Ditch	2.22	2.70	2.80	2.90	3.00	2.90	3.00	3.00	2.60	2.20
1.03	Field	1.53	1.67	1.80	1.93	2.04					
	Ditch	3.30	3.04	3.10	3.05	2.95					
2.98	Field	0.47	0.69	0.85	0.99	1.10	1.20	1.30	1.55	1.80	1.98
	Ditch	2.60	2.70	2.80	2.90	3.00	2.90	2.90	3.00	3.00	2.20
1.50	Field	1.39	1.53	1.69	1.82	1.96					
	Ditch	3.00	3.00	3.00	2.65	2.65					
0.37	Field	2.11	2.23	2.29	2.31						
	Ditch	3.00	3.00	2.70	2.50						
2.40	Field	0.94	1.17	1.30	1.40	1.52	1.62				
	Ditch	2.70	2.80	2.90	2.90	3.20	2.40				

[1]Time interval in hours after drainage began.

TABLE 3.—Average Depths to Water Table Following Various Amounts of Rainfall, in Relation to Drainage Time, in Test No. 2.

Rainfall (inches)		Avg. depth to water table at various time (in feet)[1]									
		5	10	15	20	25	30	35	45	55	70
1.50	Field	1.30	1.47	1.64	1.78	1.90					
	Ditch	3.00	3.00	3.00	2.65	2.65					
0.37	Field	2.01	2.12	2.20	2.22						
	Ditch	3.00	3.00	2.70	2.50						
2.40	Field	0.93	1.14	1.32	1.41	1.55	1.64				
	Ditch	2.70	2.80	2.90	2.90	3.20	2.40				
1.86	Field	1.10	1.28	1.32	1.35	1.37	1.39	1.45	1.86	2.02	
	Ditch	2.70	2.85	2.85	2.85	2.85	2.54	2.54	2.54	2.54	

[1]Time interval in hours after drainage began.

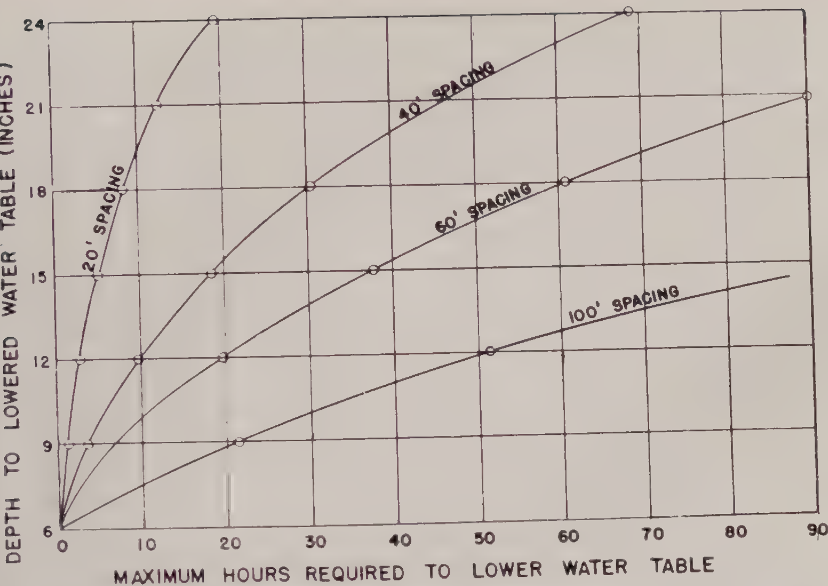

Figure 5.—Maximum accumulated time to obtain various water tables at four spacings of mole drains, as determined by application of laboratory water release data to the nomographic method reported by Visser.

12 to 18 inches, for 40 foot spacings of moles, would be 20 hours (30-10). After a rain the time required to achieve a given water table as determined from this graph must be described as a maximum because of the previously discussed evapotranspiration and conductivity considerations. A minimum initial depth to water table of one-half foot was assumed since this was the usual initial depth in field observations.

The actual average time required to lower water tables in the two field tests is plotted in Figure 4 against the various water tables obtained at given times. The time required to drain Test Area No. 2 was less than that required for Test Area No. 1, with the time difference increasing with the depth to water table. Such differences probably may be attributed to the lowered effective spacing of drains in Test Area No. 2 where buffer widths of 60 feet were employed instead of 100 feet as used in Area No. 1. A comparison of these curves with the theoretical curves of Figure 5 indicates that the overall effective drain spacing of the field tests is about 40 feet.

CONCLUSIONS

The theoretical curves of Figure 5 show that a pronounced effect of spacing should normally be expected in this soil. The maximum time required to lower the water table from 0.5 to 2 feet is 19 hours for a 20-foot spacing as compared with 69 hours for a 40-foot spacing, giving a time difference of approximately 2 days.

The failure of the field tests to yield differences in drainage rates

cannot be explained on the basis of the data obtained. Mole stoppage as a cause does not appear likely since failure would have to have been more prevalent in the closer spacings to produce the uniform water table levels observed. In future work, however, it appears that the installation of wells directly over the drains to determine the extent of stoppage would be advisable.

The encroachment of water from the non-moled buffer areas into the moled plots is a definite possibility. Here again, though, differences in water table proportionate to spacing should be expected even if reduced. To insure greater accuracy, it appears that in future work plots should be bounded by impermeable barriers or be sufficiently large to eliminate encroachment into observation sites.

The use of piezometers at various depths and horizontal distance from the drains should be incorporated into such studies to obtain a knowledge of flow patterns.

LITERATURE CITED

1. Harrison, D. S. and J. C. Stephens. 1958. We're Losing a Farming Empire—South Florida's Organic Soils are Sinking Fast. Sunshine State Agric. Res. Rept. Vol. 3, No. 1, Jan. 1958. pp 10-11.
2. Jamison, V. C. 1058. Sand-Silt Suction Column for Determination of Moisture Retention. Soil Science Soc. Amer. Proc. Vol. 22, No. 1, pp. 82-83.
3. Jones, Lewis A., Soils, Geology, and Water Control in the Everglades Region. Bulletin 442, University of Florida Agriculture Experiment Station. March 1948.
4. Visser, W. C. 1954. Tile Drainage in the Netherlands. Netherlands Jour. Agr. Science 2: 69-87.

Influence of Fertilizers Containing Superphosphate on the Soluble Sulfate and Phosphate of Blanton Fine Sand*

J. R. NELLER**

In many areas of Florida there is a distinct need for a source of sulfur for growth of shallow rooted legumes such as white clover (8). Because of this widespread response to sulfur, interest has been directed to the sulfur status of soils in Florida. It has been found that the soluble sulfate content of the surface horizons of many of these soils is low, particularly those of a sandy nature and low in organic matter. Tests showed that even where these soils are well supplied with a sulfur carrying fertilizer, their surface horizons are generally critically low in sulfate after a season of soil leaching by summer rainfall.

The nutrient sulfur investigations were extended to determine the sulfate content of deeper lying sections of the soil profile. It was found that a soil with little or no soluble sulfate in the surface profile often contained considerable soluble sulfate in subsurface layers (9). The indications are that the sulfate content varies with the clay content or with certain types of clay and this subject is under investigation.

These accumulations or supplies of sulfate may occur in native unfertilized soils. The question arises as to the source of sulfate. In some cases it may relate back to mineralogical processes in the parent material from which the soil was formed. However, since the average annual amount of rainfall sulfur in rural areas amounts to 5.4 pounds of sulfate sulfur (4), and since much of the rainfall percolates down through the sandy soils of Florida, it is conceivable that large amounts of sulfate will accumulate in a soil provided there exists a medium that will retain it. Kamprath and associates (5) report that clays can absorb and retain sulfates. In many soils the clay content generally increases with depth, sometimes rather abruptly.

The data reported in this paper relate to the sulfur status of a soil (Blanton fine sand) in which the clay content is low, generally less than two percent (Table 1), and fairly evenly distributed from the surface down through a four to five foot profile. Soil profile samples were obtained from a field of Blanton fine sand that had been well fertilized for a number of years, and from an adjacent virgin area of the same type of soil. The objective of the experiment was to determine the effect of fertilizer applications over a period of years upon the sulfate sulfur content throughout the soil profile. Since the sulfate of the fertilizer was contained in the superphosphate, the phosphorus status of the soil was also studied.

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TABLE 1.—Mechanical Analysis of Blanton Fine Sand.(1)

Horizon depth	Moisture equiv.	Soln. loss	Very coarse sand	Coarse sand	Med. sand	fine sand	Very Fine sand	Coarse silt	Fine silt	Clay
inches	%	%	%	%	%	%	%	%	%	%
0-3	5.75	3.0	0.3	9.5	33.8	40.8	10.3	3.0	0.6	1.7
3-6	2.88	1.1	0.3	8.6	29.2	43.3	12.7	3.1	0.8	1.8
6-20	2.17	0.5	0.4	7.7	29.2	33.1	13.1	2.8	0.8	1.9
20.33	1.71	0.2	0.4	7.4	28.4	45.4	13.2	2.9	0.6	1.7
33-45	0.99	0.1	0.5	7.4	25.0	47.4	15.1	3.0	0.2	1.3
45-60	1.50	0.1	0.2	5.9	22.8	48.8	17.4	3.1	0.2	1.5

(1) Physical Spectrographic and Chemical Analyses of Some Virgin Florida Soils. Nathan Gammon, Jr. et al. Fla. Agr. Exp. Sta. Bul. 524, 1953.

HISTORY OF THE CULTIVATED FIELD

Blanton fine sand is a well drained soil suitable for vegetables, tobacco and field crops. The field under study had been used for growing potatoes for a number of years. For eight years thereafter the field was used as a clover-grass pasture. During the dry months of the year it was irrigated with an overhead spray system. The field received calcic lime[a] at two, one and two tons per acre, eight, four and two years, respectively, previous to the time of soil sampling. Dolomite at 800 pounds per acre was added 2 years previous to the time of sampling. Superphosphate (20% P_2O_5 grade) was added annually and the total for the seven years amounted to 3420 pounds per acre. This amount of superphosphate carries about 1710 pounds of calcium sulfate containing 402 pounds of sulfur. An undetermined amount of superphosphate had been added for the previous crops of potatoes. The field was also fertilized with sources of nitrogen and potassium but not of the types that contain sulfur.

SOIL SAMPLING AND ANALYSIS

Composited soil samples of 10 borings each were taken of six inch sections of the soil profile down to a depth of three feet. These samples were obtained in duplicate from the cultivated field and from the adjacent virgin area. The samples were taken a year after the last fertilizer application during which time the land had been well leached by summer rainfall.

Previous work (10) has shown that Morgan's solution (6) extracts more sulfate sulfur than other types of extractants and it was used in a ratio of one part by weight of soil to 4 parts of extractant. Sulfate sulfur was determined in the extractant by a method essentially the same as that used by Chesnin and Yien (2).

Phosphates were extracted with Bray's (1) solution of 0.03 N ammonium fluoride in 0-1 hydrochloric acid using a one to five soil-ex-

(a) Dr. Sidney P. Marshall kindly supplied the pasture treatment data.

tractant ratio. The phosphorus was determined colorimetrically by the Deneges method (12).

RESULTS

The soluble sulfate of the 0-6 and 6-12 inch profiles of the cropped as well as the virgin soil was found to be low (Table 2). Below that depth there was a marked increase in soluble sulfate in the cropped field. In the virgin area there was practically no soluble sulfate above the 24 inch level in the soil horizon, and only a moderate amount in the next 12 inches. The source of the additional sulfate in the cropped soil can be attributed to the calcium sulfate of the superphosphate applications. Since the highest concentration of sulfate (64.8 ppm) was found in the 30-36 inch profile, it is evident that considerable sulfate leached below that depth. MacIntire and associates (7) have reported that the sulfate ion leaches more rapidly even than the chloride ion and that phosphates increase the outgo of sulfates.

Soluble phosphate was uniformly distributed all the way down in the profile of the virgin soil (Table 2), whereas there was 4½ times more in the surface six inches of the cropped soil, 2½ times more in the next six inches and somewhat more at lower depths. The data indicate considerable downward movement of superphosphate phosphorus, a condition that has been found to be marked in some of the sandy soils of Florida (11).

The virgin soil had about the same pH values throughout the profile (Table 2), whereas the effect of liming was clearly evident as shown by the higher values for the surface 12 inches. Below the 24 inch level pH of cropped soil horizon was slightly lower than in the virgin area. The effect of lime on the pH of the soil masked whatever influence the downward leaching of the calcium sulfate of the superphosphate may have had on soil reaction. In soil samples taken 5 years ago before this field was relimed, the pH of the four lower 6 inch sections of the profile averaged 0.35 units lower than those of the unfertilized area. This indicates an exchange of the calcium of the calcium sulfate with that of the hydrogen of the clay.

TABLE 2.—SOLUBLE SULFATE SULFUR, PH VALUES AND SOLUBLE PHOSPHORUS OF PROFILE SECTIONS OF CROPPED AND VIRGIN BLANTON FINE SAND.

Horizon	Virgin area			Cropped field		
Depths	Soluble sulfate S	pH	Soluble phosphate P	Soluble sulfate S	pH	Soluble phosphate P
Inches	ppm		ppm	ppm		ppm
0- 6	0.4	5.03	99	1.6	6.58	468
6-12	2.1	5.30	97	4.4	6.08	261
12-18	2.4	5.24	92	38.0	5.35	147
18-24	2.0	5.16	98	55.0	5.13	141
24-30	12.7	5.11	102	62.0	4.99	140
30-36	15.2	5.18	112	64.8	5.06	138

DISCUSSION

The low content of soluble sulfates found in the surface six inches of the fertilized field of this soil indicate that to insure adequate supplies of nutrient sulfur a shallow rooted plant such as white clover should be fertilized each fall after the period of summer rainfall leaching. The presence of some sulfate in the 6-12 inch profile and of much more below that depth indicates that deeper rooted legumes such as the sweet clovers might obtain sufficient sulfate residual from superphosphate applied a year previous. Since legumes require about as much sulfur as phosphorus (8), they are more likely than grasses to need annual applications of a source of nutrient sulfur.

Considerable sulfate sulfur has been extracted (3, 4, 9) from subsurface layers of soil profiles in a number of areas. Practically all of these soils have high contents of subsoil clay also, and the accumulations or deposits of sulfate appeared to vary in amount with variations in the amounts of clay. The soil for which the sulfate is reported in this paper has a low content of clay, generally less than 2 percent, from the surface all the way down through the profile; and still a very marked increase in sulfate was found below depths of about 12 inches. Why does this condition exist? Possibly it is because the leaching caused by rainfall is more complete near the surface where sulfate was applied and less complete at lower depths. The overhead spray irrigation that the field received during dry periods is not considered to have much leaching effect because most of the irrigation water must have been transpired through the leaves of the clover and grass.

The data indicate that considerable leaching of sulfate occurred and it was incomplete, since the highest concentration of sulfate was at the lowest level (3 feet) sampled. According to MacIntire (7), phosphates tend to increase leaching of sulfate. Heavy applications of superphosphate had been made on the field under study and the level of extractable phosphates was high in the surface 12 inches, the zone that was low to very low in sulfate sulfur.

REFERENCES

1. Bray, R. H., and L. T. Kuntz, 1945. The determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.
2. Chesnin, L., and C. H. Yien. 1950. Turbidimetric determinations of available sulfates. Proc. Soil Sci. Soc. Amer. 15: 149-151.
3. Ensminger, L. E. 1958. Sulfur in relation to soil fertility. Ala. Agr. Exp. Sta. Bul. 312.
4. Jordan, H. V., and C. E. Bardsley. 1958. Response of crops to sulfur on southeastern soils. Proc. Soil Sci. Soc. Amer. 22: 254-256.
5. Kamprath, E. F. et al. 1956. Effect of pH, sulfate and phosphate concentration on the adsorption of sulfate by soils. Proc. Soil Sci. Soc. Amer. 20: 463-466.
6. Morgan, M. F. 1937. The universal soil testing system. Conn. Agr. Exp. Sta. Bul. 176.
7. MacIntire, W. H. et al. 1952. Nitrogen recoveries from applications of ammonium chloride, phosphate and sulfate and outgo of complementary ions, in rainwater leachings through a six foot subsoil column. Proc. Soil Sci. Soc. 16: 301-306.

8. Neller, J. R. et al. 1951. Sulfur requirements of soils for clovergrass pastures in relation to fertilizer phosphates. Fla. Agr. Exp. Sta. Bull. 475.

9. Neller, J. R. 1955. Sulfur requirements of representative Florida soils. Annual Report of Fla. Agr. Exp. Sta. p. 148.

10. Ibid. 1956, p. 132.

11. Neller, J. R. 1946. Mobility of phosphates in sandy soils. Proc. Soil Sci. Soc. Amer. 11: 227-230.

12. Truog, E., and A. H. Meyer, 1929. Improvements in the Deneges colorimetric method for phosphorus and arsenic. Ind. and Eng. Chem. (Anal. Ed.) 1: 136-139.

The Downward Movement of Potassium in Eustis Loamy Fine Sand*

M. C. Lutrick**

Potassium is an element whose need is well established for plant growth. However, the exact role potassium plays in plant growth or its fate in soils has not been very well defined. Potassium is added in great quantities annually to our Florida soils. In many cases it is being added in excess of the amount required, while in other instances additional applications would give increased yields. This denotes a need to investigate the potassium status in Florida soils.

The study of potassium fixation and movement in soils has been quite extensive in the past. Many soils are known to fix potassium into a difficultly available form. Volk, G. W. (6) found that the removal of free alumina from clays decreased the fixing power, but with replacement of this alumina the fixing power was restored. In addition, it was reported by Volk, N. S. (7) that lime greatly increases the amount of potassium fixed by soils. These authors established the importance of free alumina and lime on soils. Further work with potassium by Jenny and Ayres (3) pointed out that the exchangeability of adsorbed potassium decreases with decreasing degree of potassium saturation. Furthermore, the complementary ion markedly affects these relationships. This means that not only the concentration of potassium but also the number and amount of associated ions are important in determining the amount of exchangeable potassium in a soil.

Some of the more recent work has been concerned with the relationship between potassium in the soil and that extracted by plants. Stewart and Volk (5) reported an average of two-thirds of the potassium from Alabama soils came from forms that were non-exchangeable at the beginning of a test in which 12 successive crops were grown to deplete the soils of potassium. According to Gammon (2), Leon fine sand showed a definite decrease in exchangeable potassium one year after adding 2.7 tons of lime per acre. On the other hand, exchangeable potassium increased with an increase in pH under a tobacco shade three years after pH treatment. A report by Craddock (1) on the Keitt plots of South Carolina, which were begun in 1913, showed that 10 pounds of K_2O above the usual 40 pound per acre rate contained consistently higher amounts of potassium at the 8-16 and 16-24 inch depths. Plots receiving 80 pounds of K_2O per acre per year were found to have doubled the amount of potassium at all levels. The major accumulation occurred at the 8-16 and 16-24 inch depths.

The work of previous investigators shows what may happen to

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potassium in many of our soils. Nevertheless, it is expedient to study each type of soil individually. It is a popular concept that potassium leaches rapidly through the profile of sandy soils. This study was undertaken to determine the extent of the downward movement of potassium in Eustis loamy fine sand.

METHODS

Two tons per acre of high calcium limestone were added to an area of virgin Eustis loamy fine sand August 22, 1957. Application was made so that the experiment would be a split plot design with lime and no lime as the whole plots. Potassium treatments, added January 22, 1958, were the sub-plots. Profile samples, containing ten cores per sample, were taken periodically. Potassium was determined on each sample using neutral normal ammonium acetate as the extractant according to Schollenberger and Simon (4). The model B Beckman Spectrophotometer was used for the potassium determination.

Samples having a soil-water ratio of 1:1.5 were allowed to stand for one hour and then the pH was determined using a Beckman pH meter.

RESULTS AND DISCUSSION

It was observed in laboratory studies that about 90 per cent of the potassium applied to a six inch column of soil was recovered in the first inch of water passed through the column. Similar results were also reported by Gammon (2). It was later found during this study that these measurements on a disturbed profile were of no value and would only lead to erroneous conclusions.

The data in Table 1 gives 42.51 inches of rainfall during the course of this study. This amount of rainfall would be considered average for west Florida. Since the downward movement of potassium is believed to be closely related to the amount and distribution of rainfall, this rainfall data should be kept in mind throughout this discussion.

The amount of potassium extracted from Eustis loamy fine sand decreased with an increase in depth as shown in Table 2. This is true of most soils where only moderate amounts of potassium have been applied. Two tons of lime per acre applied to the 0-6 inch depth

TABLE 1.—Rainfall Distribution for January to August 1958.

Period	Rainfall in Inches	Number of Times Daily Precipitation Occurred Within the Following Ranges		
		Less than 1 Inch	1 to 2 Inches	More Than 2 Inches
Jan. 22 to Mar. 15	10.43	15	1	1
Mar. 15 to May 15	6.87	9	3	0
May 15 to Aug. 15	25.21	39	4	2
Total	42.51	63	8	3

TABLE 2.—THE INFLUENCE OF LIME AND EXCHANGEABLE POTASSIUM.*

Depth of Sample Inches	Lime 2 Tons/Acre pH	Lime 2 Tons/Acre K_2O lbs./A.	No Lime pH	No Lime K_2O lbs./A.
0-6	6.5	71	5.8	67
6-12	5.9	55	5.6	49
12-18	5.8	51	5.7	48
18-24	5.6	48	5.6	36
24-36	5.5	43	5.6	30

*Each value is the average of four replications.

decreased the acidity from pH 5.8 to pH 6.5 in five months. However, the amount of potassium extracted from this virgin soil did not change as a result of liming as given in Table 2.

Potassium as muriate of potash was applied to the plots in this experiment one week after the original samples were taken (Table 3). There were 10.43 inches of rainfall between the date of application and the March sampling. It is evident in Table 3 that there was less downward movement of potassium on the limed plots than on the unlimed plots regardless of potassium treatment. In fact, the March samples indicate that where lime was applied, the 100 and 200 pounds of K_2O per acre treatments did not show any movement of potassium out of the 0-6 inch depth. On the other hand, there was some evidence of downward movement of potassium into the 6-12 inch depth in the unlimed treatments where 100 pounds of K_2O was applied. Considerably more downward movement was observed on the unlimed treatments where 200 pounds of K_2O per acre were applied. On both the limed and unlimed soils at the 400 pound per acre rate of K_2O, the potassium moved into and possibly below the 12-18 inch depth.

In May sampling, treatments which received no potassium showed a reduction in the amount of potassium extracted as compared to previous samplings (Table 3). This is probably a result of seasonal variation. There were an additional 6.87 inches of rainfall from the March to May sampling. The data in Table 3 of the May sampling does not point out much increase in the downward movement of potassium. However, some downward movement is evident at the 400 pound per acre rate of K_2O on both the limed and unlimed treatments.

The rainfall data gives 25.21 inches of rainfall between May 15 and August 15, 1958, which is the time lapse between the third and fourth sampling. There is evidence in Table 3 that some washing of soil and potassium occurred during this period on the no potash treatment. Further downward movement of potassium is shown for all treatments. For August the 100 pound rate of K_2O shows very little movement of potassium from the 6-12 to 12-18 inch depth in the limed treatment and none below the 12-18 inch depth. Although the 200 pound rate of K_2O does show more downward movement of potassium into the 12-18 inch depth than the 100 pound per acre rate,

TABLE 3.—THE DOWNWARD MOVEMENT OF POTASSIUM AS INFLUENCED BY RATE OF APPLICATION AND TIME USING MURIATE OF POTASH

Treat-ment**	Sample Depth Inches	Date of Sampling*							
		Jan. 15, 1958		Mar. 15, 1958		May 15, 1958		Aug. 15, 1958	
		L	UL	L	UL	L	UL	L	UL
0	0- 6	71	67	69	67	61	62	93	75
	6-12	55	49	54	55	44	53	55	64
	12-18	51	48	49	51	35	45	39	44
	18-24	48	36	----	----	37	44	36	29
	24-30	43	30	----	----	34	36	31	28
100	0- 6	71	67	146	139	145	156	107	104
	6-12	53	54	50	62	49	67	72	100
	12-18	49	47	47	57	40	48	56	76
	18-24	44	47	----	----	34	46	31	49
	24-30	37	40	----	----	32	37	31	30
200	0- 6	74	63	209	190	171	213	160	123
	6-12	57	51	59	102	57	102	124	137
	12-18	53	45	51	76	48	63	80	121
	18-24	47	40	----	----	41	48	48	66
	24-30	41	35	----	----	39	41	33	43
400	0- 6	64	59	364	260	338	289	187	123
	6-12	49	54	136	171	136	185	192	228
	12-18	47	42	84	110	94	130	174	242
	18-24	42	39	----	----	58	90	98	124
	24-30	37	31	----	----	49	58	44	71

*Each value is the average of four replications.
**Potassium was applied January 22, 1958, lbs. K_2O/A. as KCl.

L=Limed

UL=Unlimed

none was found below the 12-18 inch depth on the limed treatment. The August sampling in Table 3 points out very strikingly that greater downward movement of potassium occurs in the unlimed soils than in the limed soils.

It may be observed in Table 4 that the potassium applied as potassium calcium pyrophosphate* did not move downward as rapidly as the muriate of potash in Table 3. The application of potassium calcium pyrophosphate was made one week after the original sampling in January. The unlimed treatments in Table 4 show a larger downward movement of potassium, just as in Table 3. After 42.51 inches of rainfall which fell between the application of the potassium calcium pyrophosphate and the August date of sampling, movement of potassium did not occur below the 6-12 inch depth on the lime treatments of the 200 or 400 pound per acre rate of K_2O (Table 4). Also, samples taken in August on the unlimed treatments (Table 4) shows that potassium did not move below the 6-12 inch depth of the 200 pound rate of K_2O. Possibly only a very small amount of movement occurred on the 400 pound rate of K_2O below the 6-12 inch depth of the unlimed treatments. It is quite evident from the above

*The potassium calcium pyrphosphate was obtained through the compliments of the Division of Chemical Development TVA.

TABLE 4.—THE DOWNWARD MOVEMENT OF POTASSIUM AS INFLUENCED BY RATE OF APPLICATION AND TIME USING POTASSIUM CALCIUM PYROPHOSPHATE

Treat- ment**	Sample Depth Inches	Date of Sampling*							
		Jan. 15, 1958		Mar. 15, 1958		May 15, 1958		Aug. 15, 1958	
		L	UL	L	UL	L	UL	L	UL
200	0- 6	67	59	154	121	164	105	134	134
	6-12	51	52	52	59	45	55	66	105
	12-18	47	43	48	55	42	52	41	47
	18-24	40	41	—	—	34	44	29	33
	24-30	36	35	—	—	32	37	27	28
400	0- 6	72	58	239	310	230	209	225	216
	6-12	51	51	55	67	47	61	69	94
	12-18	49	45	48	53	44	55	38	56
	18-24	44	47	—	—	39	49	31	42
	24-30	34	30	—	—	34	40	27	37

*Each value is the average of four replications
**Potassium was applied January 22, 1958 lbs. K_2O A. as KCl Pyrophosphate.
L=Limed
UL=Unlimed

data that none of the potassium calcium pyrophosphate moved out of the root zone of most crops.

CONCLUSIONS

Potassium as muriate of potash does move downward in the Eustis loamy fine sand of West Florida. However, liming these soils reduces the rate of the downward movement of potassium. The lowest treatment of K_2O per acre used in this experiment was almost twice the amount recommended for use in row crop production. Therefore, it may be concluded that a normal application of potassium will not leach beyond the root zone during the growing season of most field crops. Side-dressing with potassium would be justified only if a crop required a greater quantity of potassium at a particular stage of growth than the soil could supply.

Potassium calcium pyrophosphate moved very little in the eight month period covered by this experiment.

LITERATURE CITED

1. Craddock, G. R. Soils may store potassium for plant use. South Carolina Agr. Exp. Sta. Annual Report. Page 15. 1958.
2. Gammon, Jr. N. The behavior of potassium and potassium fertilizers in Florida soils. Crop and Soil Sci. Soc. of Fla. 17:156-160. 1957.
3. Jenny, H. and Ayers, A. D. The influence of the degree of saturation of soil calloids on the nutrient intake by roots. Soil Sci. 48:443-459. 1939.
4. Schollenberger, C. J. and Simon R. H. Determination of exchange capacity and exchangeable bases in soil-ammonium acetate method. Soil Sci. 59:13-24. 1945.
5. Stewart, E. H. and Volk, N. J. Relationship between potash and soils and that extracted by plants. Soil Sci. 61:125-130. 1946.
6. Volk, G. W. The nature of potash fixation in soils. Soil Sci. 45:263-276. 1938.
7. Volk, N. J. The fixation of potassium in difficultly available forms by soils. Soil Sci. 37:267-287. 1934.

SYMPOSIUM: WEED CONTROL

Weed Control — A Continuing Challenge[1]

Ellis W. Hauser[2]

It was indeed a privilege to receive an invitation to discuss with you some of the weed control problems, current progress, and potentialities of weed control research in the Southeastern area.

Present estimates indicate that the losses caused by weeds now exceed four billion dollars annually for the United States alone. Various factors contribute to this staggering monetary loss. Weeds compete directly with the crop for various environmental necessities. Weeds increase the cost of production and may reduce the quality and purity of the farm product. They are poisonous to livestock and may endanger the health of human beings. Also, the presence of noxious weeds, especially perennials, decreases the value of farm land.

Chemicals were first used as herbicides before the turn of the century, but the major breakthrough occurred with the discovery of the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D). Advances in chemical weed control practices since the advent of 2,4-D have been spectacular. Following World War II, a number of new herbicides were introduced. Some of them were chemically related to 2,4-D, but others were not similar either in structure or in mode of action. The introduction of new materials provided much of the stimulus that has caused rapid expansion of weed control and elevated this field to an important scientific discipline. It should be remembered, however, that while chemical compounds are valuable tools in the fight against weeds, they supplement, not replace, sound cultural weed control methods and other good agronomic practices such as the use of clean seed and good seedbed preparation.

In the Southeast, there exists a diversity of weed species and weed problems. Much progress is being made in each phase of weed control research through the cooperative efforts of public scientists, extension workers, and industrial personnel. Let us examine briefly some of the principal weed control problems and current research efforts in the southern states.

CONTROL OF WEEDS IN FIELD CROPS

Probably more research effort with herbicides has been devoted to cotton than to any other major crop. As a result of this research, isopropyl N-(3-chlorophenyl) carbamate (CIPC) and 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron) are recommended in several states

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for pre-emergence control of annual weeds. While results with these compounds have been satisfactory in most situations, herbicidal efficiency and selectivity are erratic on some soil types and with some annual weed species. Also, the relatively high cost of CIPC often limits its use. For post-emergence spraying, oils have been generally accepted experimentally, but farmer acceptance has been low. If not properly used, oils are very injurious to the cotton plant. In looking toward the future, the development of a consistently effective post-emergence chemical non-phytotoxic to cotton would be an ideal solution to the cotton weed control problem.

Chemical weed control in some of the other major field crops has progressed at a rapid rate. The herbicide 2,4-D has been extensively used for pre-emergence and post-emergence control of weeds in corn. Other materials that are promising for this crop include 2-chloro-4,6-bis (ethylamino)-s-triazine (simazin) and ethyl-di-n-propylthiolcarbamate (EPTC). Intensive research has been devoted to weed control in peanuts, and four states now recommend sodium 2,4-dichlorophenoxyethyl sulfate or the alkanolamine salt of 4,6-dinitro-o-secondarybutylphenol for pre-emergence weeding of this crop. Several other compounds including tris-(2,4-dichlorophenoxyethyl) phosphite, simazin, and EPTC show potentialities in research trials. In Georgia, when used with an integrated scheme of culture designed primarily to control southern blight, pre-emergence weed control has contributed to record yields of peanuts. There are no general recommendations for weed control in soybeans and grain sorghum in the southern area. More intensive research for weed control measures in these two crops is needed.

WEED CONTROL IN HORTICULTURAL CROPS

Income from horticultural crops is very important in all southern states and especially in Florida. Weeds have always harassed the truck farmer and orchardist and have been one of the principal problems in economical production. The cost of hand weeding, even where labor is available, may prohibit growing vegetables in otherwise suitable areas. Research progress for weed control in horticultural crops has been outstanding during the past few years. In Florida alone, chemicals for use as pre-emergence or post-emergence sprays in 18 different vegetable crops are either recommended for farm use or suggested for grower trials. This is indicative of real progress.

Weed control problems in citrus crops are numerous and challenging. One of the major problems in citrus groves is the control of perennial grasses such as Bermuda (*Cynodon dactylon*), para (*Panicum purpurascens*) and maidencane (*Panicum hemitomon*). All of these can be serious problems. The use of cultural methods for control of these grasses has been costly and often impractical. Other problems in citrus are the control of pasture or other grasses prior to setting the young trees, control of deep-rooted vines under mature trees, and a means of preventing encroachment into groves by aggressive weeds from adjacent areas. It is apparent that the field of horticulture offers abundant opportunity for productive research in chemical weed control.

WEED CONTROL IN GRASSLANDS AND PASTURES

In the Southeast, the importance of grasslands in the economy of the region continues to increase. In grasslands and hay crops a multitude of weed problems interfere with the establishment, maintenance, and harvest of desirable species. In South Georgia and North Florida many thousands of acres of potentially valuable grazing lands are heavily infested with palmetto, gallberry, or other undesirable species. Intensified research effort directed toward the solution of this problem is needed. In other phases of pasture work, considerable progress has been made, but much more needs to be done. Research results in the South are not conclusive for the control of annual grasses and broadleaf weeds when a grass-legume mixture is planted or for weed control where a legume is introduced into an established grass sod. More research is needed on pasture maintenance problems such as the following: (1) the control of difficult perennial weeds, such as horse nettle and wild onions in established grass-legume stands; (2) the control of summer and winter annual weeds in grass-legume pastures; and (3) the control of annual and perennial weeds in pure stands of pasture legumes. In addition, there are numerous weed control problems in hay and seed production fields. Possibly no other phase of production research in the weed control field offers more promise than work in grasslands and pastures.

AQUATIC WEED CONTROL

Weeds in waterways, lakes, and farm ponds are serious nationwide problems which are receiving an increased amount of attention. In this phase of weed control the research worker or extension specialist is faced with a host of problems ranging from an overabundance of algae to the control of flowering plants. The weedy species may be submersed, floating, or emergent. It is encouraging to note that an increasing amount of work is being devoted to this problem in the southern area.

THE ROLE OF BASIC RESEARCH

It is evident, in view of the extensive weed control problems of the South, that the opportunities for future contributions to this field on the part of industrial personnel, public research scientists, and extension personnel are excellent. In future weed control research programs there is a need for greater emphasis on fundamental research. In the fight against perennial weeds, for example, life cycle data and information on the absorption and translocation of herbicides are of great value. The nutgrass problem illustrates the need for this type data. A review of the literature for the past 40 years would show that extensive research has been conducted throughout the world for the control of nutgrass, one of our most noxious perennial weeds; yet there are few papers of a fundamental nature dealing with this problem. No experiments which described the life cycle of nutgrass under field conditions were noted. Is there a specific period in the develop-

ment of individual nutgrass plants or the population in general that would be most vulnerable to herbicidal action? We can only speculate about the possibilities. It is possible that this elusive weed would be subject to a high degree of control with herbicides now available if scientists knew exactly when to make treatments in relation to the specific development of individual plants and of the population in general.

The status of fundamental information available about most of our other major southern perennial weeds is about the same as for nutgrass; generally there is a dearth of background data on these troublesome weed species. Much of the research in any agronomic field will be less than fully effective until the storehouse of basic information is supplied adequately.

There is a great need and excellent opportunity for all of us in weed control to take part in some fundamental research. It should be emphasized that, while elaborate facilities are needed for certain phases of fundamental endeavor, every investigator can do some work of a basic nature with the facilities and resources available to him. A properly designed field trial can be just as fundamental as a laboratory study. The degree of basic work which an individual can accomplish depends largely upon his training, initiative, and imagination.

In weed control, as in every other agronomic field, a balance between fundamental and applied research culminating in the integration of basic information into farm recommendations is very important. The accomplishment of this objective is, in my opinion, one of the principal and continuing challenges of weed control.

Weed Control in Vegetable Crops

Mason E. Marvel*

Vegetable crop production in Florida is a major industry having a gross value of about 175 to 200 million dollars each year from 440,000 acres. Of the 22 major vegetables plus several minor ones in Florida, virtually all of them may be treated with weed control chemicals to advantage. This is not being done on certain vegetables where chemical weed control is being practiced as well as the chemicals being used. The recommendations reported here are from a forthcoming Extension Circular on Weed Control in Vegetable Crops.

I would like to say that the information being presented is not from any research I have conducted but is a compilation of work done by Dr. Walter Scudder at the Central Florida Experiment Station, Dr. Joseph Orsenigo and Dr. Victor Guzman at the Everglades Experiment Station, Mr. Donald Burgis at the Gulf Coast Station, Dr. Nelson Brooke at the Strawberry Laboratory and Dr. E. N. McCubbin at the Potato Investigations Laboratory at Hastings, as well as information from commercial sources.

The crops will be discussed in alphabetical order, all rates are on the basis of active ingredient per acre.

BEANS (all types)—Only 3 to 5% of the acreage is being treated. DNBP at 6 to 9 lbs. per acre pre-emergence or CDEC 4 to 6 lbs. per acre pre-emergence on sand or muck.

Post-emergence recommendations:

DNBP—3 lbs. per acre on muck

EPTC—2 lbs. per acre on sand stirred into soil at staking on pole beans

CRUCIFERS (Cabbage, Cauliflower, Broccoli, Kale, etc.)—A small percentage of the seedbeds are being treated for weed control with CDEC or CDAA at 4 to 6 lbs. per acre pre-emergence and about 5% of the cabbage acreage is being treated with CDEC at 4 lbs. per acre post-emergence.

CUCUMBERS—A very small part of the acreage is being treated with NPA at 3 lbs. per acre.

CARROTS—Very few carrots are grown in Florida, however, this crop may be treated with several herbicides both pre-and post-emergence including CIPC at 10 to 12 lbs. per acre on muck during cool weather.

Post-emergence recommendations:

CIPC—6 lbs. on muck or mineral spirits at 50 to 80 gallons per acre at 3 leaf stage or,

CIPC—4 lbs. in 30 gallons mineral spirits on muck

CELERY—This is the crop on which the most work has been done in Florida and the largest percentage of the acreage is being

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treated. Most of the seed beds are being treated with methyl bromide at 2 lbs. per 100 sq. ft or with SMDC at 75 gallons per acre as a drench.

In the field post-transplanting 75% or more of the acreage is being treated with mineral spirits at 24 to 40 gallons per acre applied directionally or with one of the newer herbicides. CDEC at 4 to 6 lbs. per acre on sand or muck is the newest and most promising treatment. There are two other treatments recommended under particular circumstances, ie., CDAA at 4 to 6 lbs. is preferred over CDEC when grasses are more prevalent than broadleaf weeds.

A combination treatment consisting of CDEC or CIPC at 4 lbs. with 40 gallons of mineral spirits should have advantages over a single chemical in that the mineral spirits will give good contact kill on weeds that have emerged and the other will give some residual weed control.

ENDIVE (Escarole and Chicory)—75% or more of the acreage in the Zellwood area is being treated with CDEC at 4 lbs. per acre on sand or muck.

LETTUCE (All types)—Very little lettuce is grown and a very small part of the acreage is being treated with CDEC at 4 lbs. per acre. There are some problems with this treatment and it should be used only on a trial basis.

ONIONS—This is another minor crop in Florida which has possibilities for future expansion. Chemical weed control is well worked out on this crop. CIPC at 4 to 12 lbs. per acre on muck or sand or CDAA at 4 to 6 lbs. on seeded onions only, pre-emergence.

Post-emergence: CIPC pelletized at 4 to 10 lbs. per acre on muck or sand.

ENGLISH PEAS—Virtually no acreage of this crop in the state, however, CDAA at 4 to 6 lbs, or DNBP at 6 to 9 lbs. may be used.

POTATOES:—Some of the acreage is being treated with DNBP at 3 lbs. per acre on sand, pre-emergence. Where grass is a problem, Dalapon at 5 to 10 lbs. per acre is suggested as a pre-emergence treatment.

SPINACH—Several chemicals have been tried with fairly good results, however, severe phytotoxicity has been experienced at times in Florida and until more is known about this, no recommendation for chemical weed control can be made.

SWEET CORN—This is a crop where 30% or more of the acreage planted on muck is being treated with 1½ lbs. per acre pre-emergence or ¾ lbs. post-emergence at the 1 inch stage or at lay-by. About ½ of the amount used on muck is recommended for sandy soils. There are several other herbicides recommended for sweet corn pre-emergence:

CDAA—4 to 6 lbs.
CDEC—4 to 6 lbs.
DNBP—6 to 12 lbs.
SIMAZIN—2 to 3 lbs.

For post-emergence:

DNBP—3 lbs. per acre on muck at the 2 to 3 leaf stage
SIMAZIN—2 lbs. at lay by on sand

Several precautions are in order here. First, 2,4-D never should be used in a sprayer that may be used for any other purpose and 2,4-D should never be used in an area where broadleaf row crops are growing. Some early sweet corn varieties are sensitive to 2,4-D.

WATERMELONS—Virtually none of the acreage is being treated for economic reasons and for the want of an herbicide which will work under varying environmental conditions. NPA at 3 to 4 lbs. per acre either pre-emergence or at lay-by does a good job if moisture content of the soil at the surface is adequate.

There are two crops of some economic importance which I have not mentioned, SOUTHERNPEAS and STRAWBERRIES. Several of the herbicides have been used on Southernpeas, however, there are no FDA label clearances for this crop specifically.

DNBP at 6 lbs. per acre pre-emergence will do a satisfactory job.

STRAWBERRIES—SMDC, DMTT and methylbromide have all been used as pre-plant treatments. They have shown considerable merit, however, there are drawbacks with each which I will not go into here. It appears at present that as a pre-plant treatment, DMTT or SMDC are the best materials from the per acre cost and ease of application standpoint.

Post transplanting treatments:

Sesone has been used for several years with poor to average results. Several new chemicals are being tested. EPTC has promise but we are not ready for a recommendation.

In closing I would like to say a little more about food and drug approval for use of herbicides. Since the enactment of the Miller Amendment, the Food & Drug Administration requires specific compliance to use of all chemicals on crops. These regulations are most rigid on vegetables and herbicides must be used to comply to these specific tolerances. Unless a chemical is specifically cleared for a specific crop, then it may not be used on that crop. Example: Southernpeas have no label clearance with any herbicide, yet several could be used if regulations permitted.

Aquatic Weed Control

Don E. Seaman*

The importance of aquatic weed control in Florida was effectively brought to the attention of the Soil and Crop Science Society of Florida in a symposium on the subject presented ten years ago (1). Since that time progress in this field has been slow compared with that in other phases of weed control, but there have been several noteworthy advances. For example, the present programs of various agencies, initiated by the early work with 2,4-D by Allison and Seale (2) and others (3,4), have brought water hyacinths under a large degree of control. The development of emulsified aromatic solvents by Bruns et al. (5) in the west, and by Seale et al. (6) and Stephens et al. (7) in Florida has provided an economical chemical control method for submersed weeds in irrigation and drainage systems. However, most aquatic weed work has been done by persons engaged in other pursuits who have been forced to cope with aquatic weeds in carrying out their regular projects. Consequently, much information has been published in miscellaneous annual reports and various wildlife conservation bulletins of limited circulation instead of appearing in more widely distributed publications.

The dearth of urgently needed basic research data in this field can be rectified only by additional trained personnel with sufficient funds to support their work. Some encouraging signs of renewed interest in fundamental aquatic weed-control research in the past two years indicate that some improvement in the situation is at hand. The Agricultural Research Service of the United States Department of Agriculture now has 8 full-time investigators engaged in aquatic and non-crop weed-control research at stations in Florida, Arkansas, Colorado, Wyoming, Montana, and Washington, as well as several part-time workers with aquatics at other stations. Several State game commissions (including the Florida Game and Fresh Water Fish Commission), the U. S. Soil Conservation Service, and the U. S. Fish and Wildlife Service also employ special investigators for aquatic weed-control projects. The recent passage of P.L. 85-500 by Congress authorizes the U.S. Army Corps of Engineers to administer a 5-million-dollar program of aquatic weed eradication in 8 southeastern States during the next 5 years. This program promises important Federal support of aquatic weed control in cooperation with State and local interests on a 70:30 fund-matching basis and should add some impetus to research as well. Chemical companies recently have become more interested in the previously unexploited aquatic weed herbicide market, and many now have aquatic weed sections added to their screening and research programs; so before long we should have a

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sizable arsenal of chemicals available for aquatic weeds as well as for other weed-control uses. We can, therefore, expect to see some expansion and growth in this neglected phase of weed-control work in the very near future.

SPECIAL PROBLEMS AND APPROACHES

Compared with crop weed-control procedures, aquatic weed control is more complicated because of various ecological, anatomical and physiological factors associated with hydrophytic weeds. Special methods and materials must be developed to deal effectively with these special characteristics. While present emphasis is given to the adaptation of existing chemicals and methods to aquatic conditions, it may be that enough differences exist in the physiology and morphology of aquatic weeds, compared with mesophytes, to allow certain chemicals to be developed for their specific control.

Chemical control methods must be varied to suit each habitat. Submersed weeds in static water, for example, are usually treated by chemicals at certain concentrations in the water, such as the use of aromatic solvents at 50-100 ppm by volume for controlling southern naiad (*Najas guadalupensis*) (8) or the use of sodium arsenite at about 4 ppm by weight (as As_2O_3) for controlling similar weeds (9). In flowing water, chemical control is often lost through rapid dilution or reduction in contact time. In this event, a chemical may be introduced at one end of a channel and allowed to mix with the water and flow as a highly concentrated "wave." The concentration of this wave and its time of contact with the weeds may both be adjusted for optimum effectiveness by regulating the rate of introduction in conjunction with the rate of water flow in the channel. Such a technique has been used successfully in the recent testing of a formulation of acrolein for submersed weed control in the rapidly-moving water of western irrigation ditches as well as in the slower-moving water of drainage canals in Florida.

A new technique has been introduced (10) involving the use of 2,4-D-impregnated clay pellets for the control of rooted submersed weeds such as milfoil (*Myriophyllum* spp.), waterweed (*Anacharis* spp.) and certain pondweeds (*Potomogeton* spp.). These pellets sink to the bottom where the 2,4-D ester leaches slowly from the pellets and is absorbed by the weeds through their roots. It has been found that this method of treating submersed weeds is very effective, and investigations are under way to study the uses of other granular and pelleted materials on aquatic weeds.

Younger (11) showed that silvex 2-(2,4,5-trichlorophenoxy propionic acid) at 0.5-2.5 ppm by weight (as the acid equivalent) is effective not only on submersed weeds including milfoil, waterweed, fanwort (*Cabomba caroliniana*) and bladderwort (*Utricularia* sp.), but on the emergent weeds such as white waterlily (*Nymphaea odorata*) and spatterdock (*Nuphar advena*) as well. The control of submersed weeds with silvex apparently depends on the maintenance of the applied concentration for 2 or 3 weeks after treatment before the effects are fully realized; so the use of this chemical may be limited to quiescent waters. Since it is non-toxic to fish up to 7.0 ppm, there

are many ponds and small lakes where silvex may be economically feasible.

Natural successions of other aquatic weeds following the eradication of one often occur, and the succeeding species may be more difficult to control than the first one. This has been true with the widespread infestations of submersed weeds following increased light penetration into the more shallow ditches and canals of southern States after the removal of water hyacinths (6, 12). On the other hand, desirable food plants for game may be "released" naturally or purposely planted in wildlife management areas following a successful weed-control program (13). Further study is required on these ecological relationships in order to avoid more serious troubles and to maintain desirable results of weed control.

Many emergent and floating aquatic weeds have hairy leaves (e.g., water lettuce (*Pistia stratiotes*) and water fern (*Salvinia rotundifolia*)) which shed aqueous sprays readily as do the waxy leaves of lotus (*Nelumbo lutea*), spatterdock, and cattails (*Typha* spp.) The use of surfactants or oil carriers is, therefore, mandatory for control of these weeds. However, oil carriers represent an additional expense, they are hazardous, and they sometimes cause immediate "leaf-burn" and thus may prevent sufficient absorption of systemic-type herbicides for adequate translocation and control. "Invert emulsions", i.e., ester formulations of 2,4-D, 2,4,5-T and related herbicides which form *water-in-oil* emulsions with diesel oil and water (19), represent an interesting new approach to this problem. These materials have sticking and penetrating properties superior to many oil-carrier sprays, with only 10-15% of the oil being required. Invert emulsions permit a considerable extension of spraying time schedules, because they are not readily washed off and may be used during rainy seasons. Since they are relatively low-volatile and are applied in coarse droplets, their spray-drift hazards are minimal even in wind velocities up to 15 m.p.h. Recent tests with invert emulsions of 2,4-D and 2,4,5-T at Plantation Field Laboratory have been successful in controlling both *Pistia* and *Salvinia*.

The emergent parts of such weeds as spatterdock, waterlilies, and alligator weed (*Alternanthera philoxeroides*), are readily killed by direct applications of 2,4-D and similar herbicides, but underwater parts are unaffected because of poor downward translocation. Some possible explanations of this are internal transport antagonism (14), rapid injury and resulting blockage of the phloem (15), or physiological immobilization of the herbicide (16). Since 2,4-D apparently moves upward better than downward in alligator weed (17), treatment of rooted stands with granular 2,4-D seems logical. More work on this approach is needed, however, since adequate control of alligator weed has been obtained only at very high rates (i.e., over 40 lb. acid equivalent per acre) with granular 2,4-D.

The translocation problem in alligator weed may be circumvented through the use of weighted emulsion systems (18). Mixtures consisting of 50% 2,4-D ester (ca. 4 lb. acid equivalent per gal. formulations), approximately 11% polychlorobenzene, 36.5% xylene and 2.5% nonionic aromatic-hydrocarbon emulsifier (percents by volume) have been used quite successfully in south Florida. Each mixture may be

adjusted to a specific gravity slightly greater than that of water by altering the proportions of the xylene and polychlorobenzene, and then the weighted mixture is added to water and sprayed at rates between 6 and 8 lb. acid equivalent per surface acre with respect to the 2,4-D. The principle involved depends on the emulsion becoming suspended in the water for a sufficient time to penetrate and kill the regenerative submersed stem nodes. The method works best as a second treatment following a preliminary "top-kill." Preliminary top-kill with 2,4-D, for example, not only makes the underwater parts of the weeds more accessible to the emulsion, but it apparently stimulates the sprouting of submersed nodes. Alligator weed nodes are probably killed more easily if they are allowed to sprout and grow 2 or 3 inches before applying the weighted emulsion.

SPECIAL DANGERS AND PRECAUTIONS

In addition to the usual dangers to livestock, domestic animals, humans, and desirable plants resulting from the use of toxic chemicals, and the necessary precautions which must be taken, aquatic weed workers must contend with the possibilities of killing fish. Fish kill may result directly from the effect of toxic chemicals on the fish, and indirectly by the destruction of food organisms or the depletion of oxygen as a result of too rapid decay of the treated vegetation in the water. On the other hand, fish populations are reduced markedly in dense stands of aquatic weeds through the effects of shading on photosynthetic food organisms, and also through the depletion of oxygen in the water by living aquatic weeds (20).

Precautions against killing fish include avoiding the use of fish-toxic chemicals altogether, the use of fairly non-toxic chemicals such as 2,4-D, and the use of chemicals at concentrations tolerated by fish providing these concentrations are phytotoxic. As an example of the latter, sodium arsenite is non-toxic to certain fish below 18 ppm (as As_2O_3), but it kills many submersed weeds at about 4 ppm (9). Where it has been necessary to clean submersed weeds from clogged waterways in order to provide for adequate drainage, irrigation and flood control, fish-toxic chemicals such as aromatic solvents have been used because more economical non-toxic materials are not available. Occasional fish kills resulting from such treatments in Florida have been vociferously criticized by various individuals and organizations that may not know of the benefits of weed control to fish production (20) and the tremendous reproductive potential of game fish in these warm waters (21). Publicity should be given to the information showing that an occasional fish kill is insignificant compared with the risk to crops, property and even human lives of inadequate aquatic weed control in Florida's waterways.

Recent research has been aimed at developing new methods and materials which are less dangerous to fish. A new program being conducted at the Alabama Agricultural Experiment Station under a contract with the U.S. Department of Agriculture will eventually test 750 compounds for effectiveness in controlling 5 species of submersed weeds. The most promising 100 compounds will be selected to determine their toxicological effects on 4 species of fish with the aim of developing effective non-toxic chemical control methods.

MECHANICAL VS. CHEMICAL METHODS

There are some situations where mechanical mowing, crushing, chopping and dredging methods are more desirable than present chemical aquatic weed-control methods. Indeed, cutter-boats are sometimes necessary to clear passageways so that spray-boat crews may treat heavy stands of water hyacinths, and drag lines are indispensable at pumping stations for clearing weeds from trash racks. If ditchbanks are sloped and stabilized with desirable grasses, mowing ditchbank weeds becomes more economical than chemical treatments; and dredging is not required so often as with vertical banks which cave in frequently. However, mowing or cutting such weeds as alligator weed and southern naiad is undesirable because this spreads living fragments of the weeds and may cause more serious infestations at other locations.

By recognizing the need for occasional silt removal and reshaping of ditches, it is possible that a combination of mechanical and chemical methods may be more economical than the exclusive use of draglines and other dredging machines for weed control. Depending on the situation, chemical weed-control maintenance is recommended for the intervals between dragline operations. Dredging operations could then be extended to every 3 to 5 years rather than every 1 or 2 years, and sometimes twice a year, as practiced at present. Thus considerable expense could be avoided in maintaining the irrigation and drainage ditches on many farms in Florida, and more efficient use of available dragline machines could then be made for silt-removal and other dredging projects.

SUMMARY

Progress in aquatic weed control has been slow compared with that in other phases of weed-control work, but recent expansion of operational and research programs of Federal, State and private agencies indicate a renewed interest in this field, and a rapid increase of information about aquatic weed control is expected soon.

Aquatic weed control is thought to be complicated by certain unique ecological, anatomical and physiological factors. A few examples of how these special problems may be met or circumvented have been discussed, including the use of pelleted herbicides for submersed weeds, the use of invert emulsions on hard-to-wet floating and emergent weeds, and the use of weighted emulsion systems for the control of alligator weed.

A combination of mechanical dredging and chemical weed control is proposed as a more economical ditch and canal maintenance procedure for farms in Florida than the present exclusive use of draglines. This procedure entails dredging when channel reshaping or silt-removal becomes necessary, and the use of chemicals for aquatic weed control during the intervals between dragline operations.

LITERATURE CITED

1. Symposium I. The control of water plants from the standpoint of water management and navigation in the lakes, rivers and canals of the south. Soil Sci. Soc. Fla. Proc. 9: 15-115. 1948-49.

2. Allison, R. V., and Seale, Charles C. Water hyacinth control through the use of 2,4-dichlorophenoxyacetic acid in different chemical forms and at various rates of application. Soil Sci. Soc. Fla. Proc. 8: 97-106. 1946.

3. Hilderbrand, E. M. Herbicidal action of 2,4-dichlorophenoxyacetic acid on the water hyacinth, *Eichhornia crassipes*. Science 103: 477-479. 1946.

4. zur Burg, F. W. The effects of certain herbicides on the water hyacinth and other aquatic plants. Soil Sci. Soc. Fla. Proc. 9: 92-99. 1948-49.

5. Bruns, V. F., Hodgson, J. M., Arle, H. F., and Timmons, F. L. The use of aromatic solvents for control of submersed aquatic weeds in irrigation channels. U.S.D.A. Circular 971. 33 pp. 1955.

6. Seale, Charles C., Randolph, John W., and Stephens, John C. Aromatic solvents for the control of the submersed water weed naiad, *Najas guadalupensis* (Spreng.) Morong. in south Florida. Weeds 1: 366-371. 1952.

7. Stephens, John C., Craig, A. L., and Seale, Chas. C. Blended solvents for control of the submersed water weed naiad in south Florida. Weeds 3: 160-170. 1954.

8. Stephens, J. C., Craig, A. L., and Harrison, D. S. Controlling submersed water weeds with emulsified solvents in south Florida. Fla. Agric. Expt. Sta., Gainesville, Circular S-97. 14 pp. 1957.

9. Lawrence, J. M. Methods for controlling aquatic weeds in fish ponds with emphasis on use of chemicals. Ala. Agric. Expt. Sta., Auburn. Prog. Rpt. Series No. 69. 8 pp. 1958.

10. Grigsby, B. H., Hamilton, R. H., and Smith, J. A new approach to the control of certain aquatic vegetation. North Central Weed Control Conf. Proceedings. Chicago, Dec. 9-12, 1956.

11. Younger, Roy R. A preliminary report on controlling aquatic vegetation in New Jersey with Kuron. Down to Earth 13: 2-3. 1958.

12. Eggler, Willis A. The use of 2,4-D in the control of water hyacinth and alligator weed in the Mississippi Delta, with certain ecological implications. Ecology 34: 409-414. 1953.

13. Martin, Alex C., Erickson, Ray C., and Steenis, John H. Improving duck marshes by weed control. U.S.D.I. Fish and Wildlife Service Circular 19. 60 pp., 1957.

14. van Overbeek, J. Absorption and translocation of plant regulators. Ann. Rev. Plant Physiol., 7: 355-372. 1956.

15. Hull, Herbert M. Anatomical studies demonstrating phloem inactivation and its dependence upon the interaction of concentrations of 2,4,5-trichlorophenoxyacetic acid and an anionic wetting agent. Plant Physiol., 32 (supplement): xliii. 1957.

16. Woodford, E. K., Holly, K., and McCready, D. C. Herbicides. Ann. Rev. Plant Physiol., 9: 311-358. 1958.

17. Aldrich, F. D. (Unpublished intra-agency report. USDA, ARS, Denver 1957).

18. Stephens, J. C. and Seaman, D. E. Controlling alligator weed in ponded water. Weed Soc. of America Meeting Abstracts. Memphis. Jan. 13-15, 1958.

19. Coulter, L. L. Inverton 245. Down to Earth, 14: 2-3. 1958.

20. Lynch, J. J., King, J. E., Chamberlain, T. K. and Smith, Arthur L. Jr. Effects of aquatic weed infestations on the fish and wildlife of the gulf states. U.S.D.I. Fish and Wildlife Service. Special Sci. Rpt. No. 39. 71 pp. 1947.

21. Lawrence, J. M. Construction of farm fish ponds. Ala. Agric. Expt. Sta., Auburn, Circ. 95, 55 pp., 1949.

Weed Control in Lawns and Ornamentals

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Weed control is a major cost item in the production and maintenance of weed free lawngrasses and nursery stock. Information can be readily obtained concerning the preplanting control of weeds and weed seeds with temporary soil sterilants. However, very little experimental or observational data is available dealing with chemical weed control during and after establishment of lawngrasses or in ornamental plantings.

From a homeowner standpoint the best way to control weeds in established lawns is to increase the competitive ability of the turf by growing healthy, vigorous grass. Cultural practices which influence the weed population in established turfgrasses are fertilizing, mowing, watering and controlling insect and disease pests.

A fertilizer program for ornamental turf should be designed to supply sufficient nutrients so that growth is maintained at a uniform rate throughout the growing season. This involves a knowledge of the rate, frequency, and time of application of the fertilizer for various lawngrasses.

If the rate of fertilizer applied is too low for the grass requirement an open turf may develop which will be subject to weed encroachment. On the other hand if excessive fertilizer is applied there is the possibility of fertilizer burn, or the turf may become matted making an ideal habitat for disease and insect pests.

Frequency of fertilization depends on the grass used. For example, bermudagrass requires 6 to 12 applications of fertilizer per year, whereas centipedegrass, if fertilized this often deteriorates rapidly.

To increase the competitive ability of the turf, fertilizer applications should be made prior to or during active growth of the grass. This insures grass growth rather than growth of the weeds.

Proper mowing is still one of the best means of controlling annual weeds. However, mowing higher or lower than recommended reduces the vigor and performance of the turf and its ability to compete with weeds.

Frequent, shallow watering or applications of excessive water are practices often associated with encroachment of weeds such as pennywort, dichondra, chickweed and crabgrass.

Weed invasion usually occurs in areas of the lawn that have been damaged or killed by insects or diseases. This is especially true on St. Augustinegrass where chinch bugs have been a problem. The judicious use of insecticides and fungicides is recommended during periods when insects or diseases are known to be prevalent.

Occasionally weeds persist in spite of good lawn management and the herbicidal control of weeds becomes necessary. Generally, one application of the amine or low volatile ester form of 2,4-D or a mix-

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ture of 2,4-D and 2,4,5-T can be used to control certain broadleaf weeds such as carpetweed, matchweed, Florida pulsey and related species. For harder to control broadleaf weeds such as pennywort, dichondra, black medic, chickweed, and purslane, two or more applications of 2,4-D may be needed at an interval of 7 to 14 days.

At recommended rates, 2,4-D will not injure established lawns of bermudagrass, zoysiagrass, centipedegrass, and bahiagrass. However, 2,4-D or 2,4,5-T may severely stunt, or even kill St. Augustinegrass especially when the grass is growing rapidly. Consequently, these materials should be used only if patches of broadleaf weeds are present and there is no objection to having the growth of the grass in a restricted area retarded for a period of four to six weeks. 2,4-D is on the market under several different trade names and should be used according to manufacturers directions and precautions. For best results, 2,4-D should be applied when the weeds are young and actively growing. It is best to avoid mowing for three to four days before and following the application. Applications should be made with a knapsack or similar sprayer. A sprinkling can or hose-on attachment can be used if not more than the recommended amount of 2,4-D is applied.

Do not use 2,4-D weed control equipment for applying insecticides, fungicides, liquid fertilizer, or within several feet of sensitive plants such as most garden vegetables, flowers and ornamentals.

Crabgrass, crowfoot, sandspur, bullgrass and other annual grasses can be controlled by using disodium methyl arsenate (DSMA). DSMA is sold under the trade names of Crab-E-Rad, Dimet, Clout, and Sodar. Since the active ingredient in these materials vary, the manufacturers recommendations should be followed. Following the initial treatment a second application will be necessary within 7 to 10 days. DSMA can be used on bermudagrass and zoysiagrass, but should not be used on St. Augustinegrass, centipedegrass, carpetgrass and bahiagrass.

Bahiagrass, bermudagrass or other perennial grasses which sometime infest lawns can be controlled by using the herbicide dalapon. Since the desirable grass is also killed by this treatment care should be taken to see that only the infested areas are sprayed. Dalapon should be applied as recommended and the grass should be thoroughly wet but not to the degree that the spray will drip off the leaves. Once the infested areas have been killed the desirable grass can be replanted three to six weeks following treatment.

Weed control in turf and ornamental nurseries can be divided into three categories; preplanting, pre-emergence and post-emergence.

Temporary soil sterilants such as methyl bromide, SMDC (Vapam or VPM) and DMTT (Mylone) are probably the best materials for preplanting control of weeds, but these items are expensive and almost prohibitive for treating large areas.

Dalapon plus 2,4-D also can be used for the initial control of perinnial grasses and broadleaf weeds, but is relative ineffective against nutgrass.

Sesone (Crag Sesone) and Simazin (Simazine) appear to be promising for the control of germinating weed seeds and seedlings. Both materials, however, are relatively ineffective against mature

weeds. Since neither material has been thoroughly tested more information is needed to determine the percent weed control and physotoxicity of the desired crop.

Cultivation; hand weeding and hoeing are still probably the most used methods of controlling mature weeds in ornamental plantings. However, PCP (Liquid flame plus an emulsifier) which is a contact herbicide is fast replacing the laborous methods of weed control. Liquid flame kills on contact and is not translocated throughout the plant therefore there is little chance of damaging the desired plants unless the spray is applied directly.

Some experimental evidence indicates that sesone can be added to Liquid flame for the control of germinating weed seed along with the control of mature weeds.

In summary, information is readily available concerning the preplanting control of weeds and weed seeds in turfgrasses and ornamental plantings.

The most effective method of weed control in established lawns results from good cultural practices supplemented with 2,4-D for the control of certain broadleaf weeds and DSMA for the control of most annual grasses. Both herbicides, however, have certain limitations because of their phytotoxicity to lawngrasses.

Certain new herbicides show promise for the control of weeds during and following the establishment of southern turfgrasses as well as in ornamental plantings. However, considerable testing is needed before large scale use can be recommended.

Brush Control

E. G. Rodgers*

Woody plants, or brush, are found in varying degrees of intensity throughout most areas of the Southeastern United States. Some species of brush have high levels of aggressiveness and a wide area of adaptation. One or more species most commonly encrouch onto areas of land that are undisturbed for a few years. Or if left undisturbed, bushy species predominate in most areas.

Control of these vigorous perennial plants is a problem of considerable concern to many agricultural and commercial interests. Clearing land for crop production commonly is more expensive and difficult because of the presence of brush. Invasion of pastures by woody plants is a continuing problem for many livestock producers, particularly in tropical and sub-tropical areas. And any farmer is aware of the rapidity of establishment of brush in his fence-rows. Although this strip of brushy vegetation in fence-rows often serves as much needed protection for wildlife, such vegetation competes severely with crop plants growing within several feet of the fence, usually resulting in failure of the crop plants to produce a harvestable yield, and most commonly detracts from the aesthetic appearance of the farm. The farmer, then, has the decision to make as to whether he will protect wildlife along the fence-row, or control the brush and use the land to maximum efficiency for production of crops.

The control of brush within utility rights-of-way is a typical problem with which various commercial organizations are concerned. Mechanical clearing of these areas when the right-of-way is established and maintenance of the area thereafter primarily by chopping are procedures that have been and still are common. Chopping brush, even with heavy choppers that pulverize the top soil as well as the vegetation that is present, provides only temporary control since the vigorous root systems of the woody plants are not destroyed and soon after the chopping serve to support renewed growth. Such chopping normally is required at intervals of three to five years to keep the vegetation in check. Numerous pulp companies presently are growing their own pine for pulp production, but they encounter competition from undesirable woody plants, such as various oak species. A control measure with some degree of selectivity, then, is desired that will take out the unwanted plants without injury to the pine.

Consideration of these brush control problems and numerous others illustrates that mechanical operations have been standard methods of control. In an effort to reduce the cost of brush control, land owners in the last decade have begun using chemical sprays. The farmer normally can control brush in his fence-row with a chemical spray much more economically than with a grubbing hoe or other mechanical device. The same spray may be used to advantage to

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eliminate the brushy plants that tend to invade grazing areas. A similar spray is being used in increasing amounts each year on utility rights-of-way. And some sprays have sufficient selectivity to be used successfully in pine plantings to kill or retard the growth of brushy plants without injury to growing pine.

The chemical or herbicidal component of these sprays must be chosen, however, for the specific job to be done. Several herbicides are available commercially for use in this manner, but some of the more commonly used ones include various ester formulations of 2,4,5-T, 2,4-D and 2,4,5-T in mixture, and 2-(2,4,5-TP). Ammonium sulfamate also is used to some extent in brush control.

Chemicals for brush control may be applied in various ways. Some of the more common methods and the circumstances under which each method may be best suited are presented:

1. Foliage spraying—Foliage spraying refers to thorough wetting of the leaves and stems of the plant with the spray. Woody plants are most easily controlled by this type of application during rapid plant growth in the spring when the older leaves on the plant or tree have just reached full size. Presumably, food reserves in the root systems are lower then than at any other time of the year from depletion by winter dormancy and initiation of early spring growth, and that downward translocation of photosynthetic materials to the roots probably is approaching its maximum rate. Since translocation of herbicides has been demonstrated to be primarily in conjunction with translocation of food materials, more of the herbicide would tend to be moved into the root system and other plant parts when applied at this growth period.

   Butoxy ethanol ester, iso-octyl ester, and propylene glycol butyl ether ester of 2,4,5-T, mixtures of 2,4-D and 2,4,5-T, or 2-(2,4,5-TP) are materials that are used commonly as foliar sprays. Approximately four pounds of active ingredient of the preferred herbicide are included in 100 gallons of water and this mixture sprayed to thoroughly wet the foliage. Since thorough wetting is essential to good control, high spraying pressures—200 to 300 psi—may be essential in dense brush. On brush having leaves with a particularly smooth surface, the replacement of 5 to 10 gallons of the water in the spray with an equal quantity of kerosene or diesel fuel aids materially in retention of the spray droplets on the leaves. A spray of this kind properly applied has been effective in killing some plants and severely stunting the growth of other plants of various oak species, elm, maple, cherry, wild grape and other similar brushy plants. Repeat applications often are necessary to kill many species such as turkey oak and sweet gum.

   A majority of foliar applications are made with ground spray equipment. Any type of sprayer is satisfactory so long as it is capable of sufficient pressure and otherwise equipped to thoroughly wet the plant. In recent years, however, aerial application of herbicides to brush without thorough wetting has been practiced in many areas. Both airplanes and helicopters have been used, but the helicopter most commonly is preferred for its greater maneuverability. In either, the total gallonage applied is about five

gallons per acre. The gallonage normally includes from two to three pounds active ingredient of the desired herbicide. Some commercial operators apply as low as three gallons per acre containing from one to three pounds active ingredient of the herbicide. One or more repeat applications usually are required for satisfactory control of most brush.

2. Stump treatment—The stumps of most deciduous trees sprout profusely after the tree is cut. To kill the stump as well as the root system, the stump should be treated immediately after the tree is cut to secure the maximum killing effect of the chemical. If immediate treatment is impractical, treatment should be made within three days or a considerable portion of the exposed cells would have dried excessively and penetration of the chemical would be retarded, resulting in a less efficient kill of the root system.

   Treatment of the stump should include a thorough wetting of the top and all sides of the stump from the cut level to the ground level. The spray solution normally includes from 8 to 16 pounds active ingredient of one of the phenoxy herbicides used for foliar spraying in 100 gallons of either kerosene, diesel fuel, or a similar oily carrier. The oil is essential for retention of the herbicide onto the stump sufficiently long for penetration of the chemical into contact with living cells of the stump for translocation throughout the root system. Brush greater than six feet in height normally is more easily killed by this method than foliar application of the herbicides. Most stumps of deciduous brushy species are readily killed by this type of treatment.

3. Basal bark treatment—Most brushy plants are killed by the basal bark treatment. The base of the tree is saturated with the spray from the ground level up to a height of 12 to 18 inches. Preferably, the soil surface should be thoroughly wetted also on all sides of the tree for an outward distance of 12 to 36 inches. The spray solution with the oil carrier and relatively high herbicidal concentration described for stump treatments is appropriately used in the basal bark treatment.

   No uniform agreement exists among research personnel as to the best season of the year for basal bark applications. Some authorities believe that treatments about three weeks before the end of the winter dormant period is best. At that time, upward movement of food materials is under way to support spring growth and with these materials, the herbicide would move upward; with the development of leaves and later downward translocation of photosynthetic materials, the herbicide also would be moved to the root system to provide thorough distribution within the tree and ultimately a complete kill. Others believe, however, that summer application is equally satisfactory or possibly best at which time the adsorbed herbicide would be moved to the root system in conjunction with the food materials being translocated downward. If the root system is killed, the tree top obviously would die also. Regardless of the time of application, good kill of brush usually results from this type of treatment when properly applied.

4. Frill treatment—The frill treatment consists of making overlapping axe cuts completely around the base of the tree 8 to 24 inches

above the ground level. Care should be taken to make the cut continuous so as not to leave any strip of uncut cambium. The chemical killer then is placed into the frill so prepared.

This treatment applies primarily to large hardwood trees rather than smaller ones. The trees may be removed later or they may be left standing for the branches to fall and the trunk to disintegrate with the passage of time. In either instance, foliage of such trees will not hinder the growth of desirable tree species, such as pine.

An ester formulation of 2,4,5-T at a concentration of about four pounds per 100 gallons of kerosene or diesel fuel used to fill the frill will kill most hardwood species, including most oak, sweetgum, and similar woody plants. Ammonium sulfamate (ammate) also may be used effectively in this manner by mixing about four pounds of the yellow crystalline ammate in one gallon of water; or about one tablespoonful of the ammate crystals may be placed directly into the frill of each tree. Sodium arsenite also has been used extensively in this regard. Its use is economical and gives relatively quick kill of most species. It usually is used as a solution consisting of from three to five pounds of dry sodium arsenite per gallon of water for application in the frill. The solution may be mixed at home, but a safer and more common procedure is to secure the solution already mixed, since this material is a deadly poison. Extreme caution should be exercised in its use not to allow it to contaminate clothing or get on the skin. All empty containers used earlier to store or mix the material should be destroyed. Frill treatments usually are more effective when applied in the spring when young leaves are developing, but sodium arsenite often has shown quicker effect when applied during summer or early fall months.

5. Soil sterilization—Sterilization of the soil has not been used as much in brush control programs as the methods described above. However, research results[1] during the last three years indicate this method may have considerable potential for practical use in circumstances where no other plants are to be grown on the land within two or three years after treatment with the sterilizing material. Monuron and diuron at minimal rates of 10 pounds per acre have killed turkey oak and several other hardwood species that foliage sprays described earlier do not completely kill. Turkey oak is not killed during the season of herbicide application nor the first season thereafter, but the plants are dead at the beginning of the second growing season after treatment. Further studies have indicated that this rate of application may be reduced by approximately one-third by applying the material in bands about 20 inches wide alternating with unsprayed bands 40 to 80 inches in width. Since root systems of the woody plants normally extend several feet in all directions away from the base of the tree or bush, sufficient material will be absorbed by roots in the treated strips to be lethal to the plant. Further studies on strip application of soil sterilants appear justified to determine more specifically the minimal application rates required for kill of particular species.

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[1]Unpublished results of E. O. Burt and the author.

Controlling brush differs from controlling annual or other non-woody plants in that brush plants normally are much larger and respond much slower to herbicidal treatment than non-woody plants. A period of from one to two years commonly is required for most herbicides to exert their killing effect. Several months or possibly a year may elapse after treatment before injury symptoms appear. However, response to foliar applications is most rapid and usually is evident within 7 to 21 days after treatment.

In summary, brush control is a continuing problem, particularly in undisturbed areas. Mechanical procedures have been standard methods of brush control, but the use of chemicals has become much more common during the past decade. The specific type of control problem will determine largely the particular herbicide to be used and the method of its application. Small brush usually is treated with an ester formulation of 2,4,5-T or related phenoxy herbicide as a foliar spray, while larger vegetation may be treated with these herbicides on the basal bark or in a frill, or the tree might be cut and the remaining stump treated to prevent sprouting. Soil sterilization shows practical use for control of either small or large vegetation on land where no desirable plant is to be grown for a period of two to three years.

Weed Control In Florida Field Crops*

E. O. Burt**

INTRODUCTION

Weed control is one of the major items of expense in producing field crops. High cost of labor during the past few years has created the need for more economical methods of weed control. Research on the use of herbicides, in conjunction with other good management practices, has resulted in better control of weeds at less expense to the farmer. Most states in the southern United States have conducted research on control of weeds in field crops (3). The results from such research cannot be applied to other areas without a degree of reservation. For example, the Georgia Agricultural Experiment Station recommends (1) the use of sesone (sodium 2,4-dichlorophenoxyethyl sulfate) for control of weeds in peanuts, while the Florida Agricultural Extension Service recommends (2) DNBP (4,6-dinitro ortho secondary butylphenol) for the same purpose. The information reported herein is a summary of the results of experiments conducted at Gainesville and certain Branch Stations in north Florida from 1954 to 1958, inclusive, on the use of herbicides for control of weeds in peanuts, field corn, soybeans, oats and pastures.

EXPERIMENTAL PROCEDURE

A total of 44 weed control field experiments were conducted during the 1954-1958 growing seasons on field crops as follows: 18 tests with peanuts, 8 with corn, 7 with soybeans, 3 with oats and 8 with pastures. These tests were conducted on sands, loamy sands or sandy loams. A randomized block design with three or four replications was used in each test. In most of the tests plots were 12 2/3 feet by 30 feet in size. Herbicides were applied as aqueous sprays at rates of 10 gallons of spray material per acre in the experiments with oats and pastures and at rates of 25 to 40 gallons per acre with peanuts, corn and soybeans. Post-emergence treatments were used on oats and pastures, while with the other three crops both pre-and post-emergence applications were made. All rates of herbicides were on the basis of active ingredient. Herbicides were used at three or four different rates in order to determine degree of weed control and safety to the crop.

Visual ratings were made periodically throughout the growing season to determine degree of weed control and injury to the crop. Crop yields were obtained from the most promising treatments.

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RESULTS

Peanuts

Effective (75 to 100 per cent) control of annual grasses and annual broadleaf weeds has been obtained by the use of DNBP at the rate of 9 pounds active ingredient per acre when applied pre-emergence to peanuts as indicated from 18 experiments conducted during a five year period at five locations.

Sesone has given equally as good results in four of the tests but poor weed control and or injury to peanut plants has occurred in the remaining trials. A comparison between the climatological data and the data on herbicidal effectiveness indicates that a moist soil surface within two weeks after treatment is necessary to activate sesone. On the other hand, heavy rainfall—3 inches or more—may leach sesone to the extent that peanut plants will be stunted. Greenhouse studies[1] substantiate these field results. DNBP has been effected to a lesser degree by soil moisture than has sesone.

The following herbicides at the respective rates in pounds of active ingredient per acre have given good to excellent control of weeds in peanuts, but under high rainfall have resulted in herbicidal injury to peanut plants: Sodium pentachlorophenate (sodium PCP) at 8 and 12 lb A, low volatile ester of 2,4-dichlorophenoxyacetic acid (2,4-D) at 2 lb A; 3-(3,4-dichlophenyl)-1,1-dimethylurea (diuron) at 1 and 2 lb A; 2-chloro-N,N-diallylacetamide (CDAA) at 8 and 12 lb/A; tris(2,4-dichlorophenoxyethyl) phosphite (Falone) at 2 and 4 lb/A; 2-chloroallyl diethyl-dithiocarbamate (CDEC) at 8 and 12 lb/A; and ethyl N,N-di-n-propylthiolcarbamate (EPTC) at 5 and 10 lb/A.

The results of a single experiment in 1958 incorporating EPTC and four analogs of EPTC into the soil indicate that the effectiveness of these herbicides can be greatly increased by incorporating the chemical into the upper 2 to 4 inches of soil. This was accomplished by preparing a seedbed, applying the herbicides, disking the area lightly, and then planting the peanuts.

The four analogs of EPTC which were used at rates of 1, 2, and 4 pounds per acre include: ethyl allyl-n-propylthiolcarbamate (R-2181), ethyl diallylthiolcarbamate (R-2007), propyl ethly-n-butylthiolcarbamate (R-2061) and n-propyl di-n-propylthiolcarbamate (R-1607). The following treatments gave very good control of weeds with little or no injury to peanuts: EPTC at the 1 and 2 pound rates, R-2181, R-2061, and R-1607 each at the 2 and 4 pound rates, and R-1607 at the 1 pound rate.

DNBP also has given good results as an early post-emergence treatment on peanuts. Three pounds active DNBP per acre when applied to weeds soon after emergence has given 100 per cent kill of annual weeds. When application of DNBP was delayed until weeds were more than 1 or 2 inches in height, poor weed control resulted. DNBP "burned" peanut foliage and temporary stunting resulted but the plants recovered within seven to fourteen days and yields were 100 to 600 pounds per acre higher than in plots receiving normal cultivation.

[1]Unpublished results by Earl G. Rodgers and the author.

DNBP at the rate of 3 pounds active ingredient per acre gave practically no residual weed control; consequently, a combination of DNBP and sesone was used in nine experiments with peanuts. An early post-emergence application of DNBP at the rate of 3 pounds per acre in combination with sesone at 2 to 4 pounds per acre gave 80 to 100 per cent control of young weeds. The residual effects of sesone prevented new weeds from becoming established for a period of four to ten weeks.

The above rates are on the basis of treating the entire soil surface. A 12- to 16-inch band directly over the drill row may be treated instead of the entire soil surface, thus reducing the quantity of herbicide needed to treat an acre of peanuts. Weeds in the area between the treated band can be controlled by normal cultivation. During such cultivation fenders or other protective devices should be used to prevent untreated soil from being moved into the treated band.

Corn

Results from eight experiments with field corn indicate that 2-chloro-4,6-bis (ethylamino) -s-triazine (simazin) at 1 pound per acre, EPTC at 5 and 10 pounds per acre, and CDAA at 8 pounds per acre as pre-emergence treatments or 2,4-D at the rate of ¼ to ½ pound per acre (ester formulation at the lower rate or amine formulation at the higher rate) as a post-emergence treatment are highly effective in killing annual broadleaf weeds. Simazin and EPTC as pre-emergence treatments were effective in controlling annual grass weeds also.

Other pre-emergence herbicidal treatments which gave good control of annual weeds in one or more of the tests are as follows: CDAA at 8 and 12 lb A, CDEC at 8 and 12 lb A, DNBP at 9 lb A, 2,4-dichlorophenoxyacetamide (2,4-D amide) at 2 and 4 lb A and diuron at 1 lb A. These treatments have not given results as satisfactory as simazin, EPTC and CDAA.

Early post-emergence application of DNBP at the rate of 3 lb A has given good to excellent control of weeds with slight temporary stunting of corn plants.

Soybeans

The results from eight experiments with soybeans indicate that sodium PCP at 8 and 12 lb A is the most satisfactory pre-emergence treatment; CIPC at 6 and 9 pounds per acre gave nearly as good results. EPTC at rates of 5 and 10 lb A gave good control of weeds in most of the experiments but resulted in stunting of the soybeans.

Oats

Three experiments were conducted in which oats were treated at three different stages of growth with different herbicides at different rates. Oats were treated at the 2- to 3-leaf stage, 3- to 4-leaf stage and when they were beginning to joint. The amine formulation of 2,4-D at the ½ pound per acre rate gave very good to excellent (85 to 100 per cent) control of broadleaf weeds with no injury to oats. The yield of oats was increased 3 to 8 bushels per acre. The higher the weed population, the greater was the increase in yield from the use of 2,4-D.

The amine formulation of 2,4-D at rates 3 pounds or more per acre reduced yields of oats. The low volatile ester formulation of 2,4-D was more toxic to oats and weeds than the amine formulation. The ester formulation gave good control of weeds with no injury to oats at the ¼ pound per acre rate, but significantly reduced the yield at the 1½ pound per acre rate.

The amine and ester formulations of 2-methyl-4-chlorophenoxyacetic acid (MCPA) were less toxic to weeds than the respective formulations of 2,4-D.

3-amino-1,2,4-triazole (amitrol), DNBP and 2,3,6-trichlorobenzoic acid (2,3,6-TBA) did not give satisfactory weed control and/or injured oats.

The results indicate that the best time to treat oat plants is when they are in the 3- to 4-leaf stage, although treatments made at the 2- to 3-leaf stage, or when oats were beginning to joint, gave nearly as good results. Oats were slightly more susceptible to herbicidal injury at the early stage of growth or when they were beginning to joint.

Pastures

The results from eight experiments on control of weeds in grass pastures indicate that 2,4-D at rates of ¼ to 1 pound per acre is effective in killing most species of broadleaf weeds. Weeds that were young and growing rapidly were more susceptible to 2,4-D than mature weeds of the same species. Dog fennel (*Eupatorium capillifolium* (Lam.) Small) less than 1 foot in height and growing rapidly was killed with 2,4-D at the rate of 1 pound per acre, while mature plants of this species were not killed by the 4 pound per acre rate.

St Augustinegrass is the only pasture grass commonly grown in Florida that has been injured by 2,4-D at rates which are necessary to control broadleaf weeds.

Annual grasses were controlled in perennial grass pastures by two applications of disodium methyl arsenate (DSMA) at the rate of 6 pounds active ingredient per acre per application. St. Augustinegrass and centipedegrass were injured by this herbicide. The high cost per acre of this treatment greatly limits its use in low value crops.

LITERATURE CITED

1. Georgia Agricultural Extension Service. *Growing Peanuts*. Ext. Cir. 309. 1955.
2. Rodgers, Earl G., Evert O. Burt and Aubrey C. Mixon. *Chemical Weed Control in Peanut Fields*. Fla. Agr. Ext. Serv. Cir. 146. 1956.
3. *Southern Weed Conference Proceedings*, Vol. 1 through 11, 1947-1958.

FIBER CROP SYMPOSIUM—GENERAL SESSION

The Place of Natural Fibers in National Defense

Mathias W. Niewenhous*

The Office of Civil and Defense Mobilization, on behalf of the President, manages and directs both civil defense and defense mobilization programs of the United States.

The head of each Federal department and agency, in coordination with the Director of OCDM, plans and conducts such civil defense and defense mobilization activities as are inherent in his normal responsibilities or as he may be assigned by the Director of OCDM. All agencies having resources or competence related to civil defense and defense mobilization programs assist the agencies having primary responsibilities. I am in the Division having jurisdiction over production and materials and my responsibility is in the field of forest products and natural fibers.

The probabilities of demand for fibers in time of war are determined by OCDM after consultation with the various interested Government departments. Problems of supply and requirements are weighed and objectives determined. The mobilization base estimated requirements in many instances bear no relationship to the experience of World War II. Moreover, changes in planning, based on assumptions as to the type and length of future wars, have brought about substantial changes in estimated defense requirements. This has, in some cases, resulted in reductions in estimates of the need for natural fibers.

As you know, the Government has maintained stockpiles of certain natural fibers, such as abaca, sisal, long staple cotton, and silk, against defense needs. The stockpiling goals on these fibers were originally determined on the basis of a concept of a 5-year emergency. However, with the reduction in estimated defense requirements for many fibers, for one reason or another, including the assumption of a 3-year emergency instead of a 5-year emergency period, the present stockpile accumulations are in general not out of line.

I am unable to discuss quantities with you because both stockpile accumulations and defense requirements are classified information. Since you all are familiar with end uses and most major defense applications of natural fibers, I see no point in discussing this aspect of the matter. In general, however, I would say that the maintenance of an adequate supply of natural fibers in our planning remains vitally important to a defense effort. It is true that more and more man-

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*Director, Division of Production and Materials, Office of Civil Defense Mobilization, Washington 25, D. C. Mr. Niewenhous was unable to be in St. Petersburg at the time of the meeting due to prevailing strikes in the air transportation service. His paper was read by Mr. E. G. Nelson, U. S. Department of Agriculture, Beltsville, Md.

made fibers are becoming available in greater quantities and that to some extent we can plan on the use of these man-made fibers in the place of natural fibers. To meet the competition from man-made fibers I would stress the growing of quality natural fibers. I do not mean to imply that eventually man-made fibers will replace natural fibers, because in my opinion there will always be an important place for natural fibers in our economy.

I understand that during and after World War II there were many predictions on the impact of nylon and other man-made fibers, then in process of development, on the use of natural fibers. To a limited extent some of these predictions have come true but, in the main, natural fibers, insofar as defense uses are concerned, are still preferred in most applications. For example, as you all know, nylon has practically eliminated most of our requirements for silk. This fiber, along with some other man-made fibers, to a limited extent has displaced the use of natural fibers such as cotton, wool, jute, and abaca in certain items of clothing, equipment, or supplies in defense uses.

There may be occasions from time to time where a reliance on man-made fibers might prove more economical. An instance of this is the Government's recent action in deciding to liquidate the abaca plantations in Central America. These plantations have been kept in operation for some years after World War II pending the recovery of production in the Philippines and later as a kind of stockpile in the ground as a supplement to the national stockpile of fiber. However, in the interest of economy and with the adoption of the concept of a 3-year emergency it becomes no longer practical to maintain the operations, especially in view of the availability of man-made fibers to make up any deficiencies.

While man-made fibers very often have similar qualities or in some respects are superior to natural fibers for certain uses, the acceptability of these fibers in substitution for natural fibers has been greatly retarded by their relatively high initial costs, which are not wholly offset by longer service. Perhaps they will make greater inroads in the future when cost differentials narrow. In any event, it presents a great challenge to the producers and users of natural fibers to improve their products in every way by research for better and better materials or products.

Review of Role Played by the Soft Fibre Manufacturing Industry in World War II and Possibilities in a Future War.*

George F. Quimby**

This subject naturally divides itself into two parts. We shall first review the "role played by the soft fibre manufacturing industry in World War II" and later make a few observations on "possibilities in a future war."

This review is based partly on fragmentary records found in the National Archives from which the "Confidential" Classification has been cancelled, and on the memories of industry officials who were active during the war.

The story is nowhere near complete either from available government files or from member companies of the soft fibre manufacturing industry. Old files have a habit of being destroyed when people die or retire and when time and storage space limitations dictate.

Well in advance of the United States entry into World War II—and before the War Production Board was set up—the Textile Division of the Advisory Commission to the Council of National Defense—in 1940—called upon the spinners in the soft fibre manufacturing industry to offer voluntary allotments of flax fibre, flax yarn and linen thread for a program of national defense. Later the War Production Board established a Textile, Clothing and Leather Division with ten branches. The Cordage Branch was one of these and it handled all matters concerning:

Binder Twine
Brattice Cloth
Burlap Importing and Bag Manufacturing
Cordage
Flax
Istle
Jute Bale Covering Weavers
Jute Spinners

(Fishnet manufacturers were under the Equipage Branch.)

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*Review presented at first meeting of Soft Fiber Task Group, Business and Defense Services Administration, U. S. Department of Commerce, Washington, D. C. on November 19, 1958.

**Secretary and Treasurer, Soft Fiber Manufacturers' Institute, Wilton, Conn.

NOTE: Mr. Quimby's report is of very great value as an historical document in showing what an amount of confusion and danger can develop at a critical time when activities essential to supply of a critical material are neglected during peace time. Even now many people are wondering how we are so calmly overlooking the production possibilities in Mexico where just about any amount of almost any fiber could be produced at any time by virtue of land adaptability and the growing need for work of this type for an ever burgeoning reservoir of labor especially when coupled with the fact that we have about 1500 miles of land boundary in common with this great neighbor to the south.—Ed.

In the National Archives records I find the following undated (about 1942) statement by the late Arthur R. Howe, who was the first Chief of the Cordage Branch W.P.B.:

"The most important use for *Jute,* which is in turn the most important of the soft fibres from the angle of availability and size of crop, is the manufacture of burlap. Jute is also used to make sugar bags, wool sacks, ore sacks, and in addition and to a lesser extent it is used for rope, twine, carpet backing, electrical yarn and roving, and many miscellaneous items of less importance. The chief use for Jute is as a carrier of agricultural and other commodities.

Substantially all the burlap manufactured in the world is manufactured in Calcutta. A small amount is manufactured in Dundee. None is produced here.

The chief use of Jute in this country up to two years ago was the manufacture of carpet backing or carpet yarn used in the manufacture of carpets. Next in importance is the manufacture of Jute twine, electrical yarn and roving, yarns for reinforcing paper," for use in safety fuses, "the manufacture of webbing used largely for upholstery purposes, and several miscellaneous and less important products.

The chief world use of *Flax* is in the manufacture of fabrics. In this country the industry produces practically no fabric with the exception of crash towels and has been devoted to the production of high grade threads and twines.

Hemp, that is true hemp, as contrasted with manila or abaca fibre, has been used largely in the production of twine prior to the war.

Ramie, while having caught the interest of many, has never been used to any great extent in this country. Its chief use since the war has been very limited and that is particularly true since supplies from China and the Philippines have been cut off.

Coir fibre from the fibrous shell of the cocoanut is used to make door mats and twine and on polishing rolls in industry. Coir rope is not as strong as rope made from any of the hard fibres or from the soft fibres. However, Coir fibre has great resistance in water and its use is increasing."

In an unfinished "History of the Cordage Branch," also without date—but apparently written late in 1944—the story of *Burlap*—the jute fabric—was recorded as follows:

"*Burlap* was the most important product of the soft fibres because it was apparent that there would be a large military demand and it was needed for carrying the crops of the country."

"The control and distribution of *burlap* was the most pressing problem so far as any soft fibre product was concerned because military demand from the day of Pearl Harbor increased enormously, and during 1942 two-thirds of all burlap arriving in this country was set aside and used by the military forces for the manufacture of sand bags and camouflage. The remaining one third was distributed for the manufacture of agricultural bags. This

was not sufficient to meet the demand for bags but we were fortunate in being able to supplement the supply with cotton cloth suitable for manufacture into bags capable of carrying crops. Control Order M47 conserves and directs the use of *burlap* to what are regarded as the most essential uses."

The fabric burlap and its importance as a soft fibre product has a legitimate place in this review even though, as Mr. Howe wrote, it is not now produced in the United States. The first quantity end use of kenaf in this hemisphere is for fabrics made into bags and sacks to carry sugar, coffee et cetera.

The other soft fibre fabric mentioned by Mr. Howe, is linen toweling made from flax in this country by Stevens Linen Associates of Webster, Massachusetts.

The soft fibre manufacturing industry in the United States comprises principally the spinners of *linear* products from jute, flax and soft hemp (cannabis sativa)—the basic item being yarn.

The Cordage Branch History, already quoted, states that:

> "In November 1941 it was apparent that the supply and control of cordage fibres and their products was to become a serious problem. Two consultants were appointed—one to deal with hard fibres, the other with soft fibres. The most important use for manila and sisal . . . was for the manufacture of rope.
>
> Action was taken to freeze manila well before Pearl Harbor. The manufacture of twine was not permitted. Conservation orders were written for burlap two weeks after Pearl Harbor; jute about four weeks after Pearl Harbor; and sisal approximately six weeks afterward.
>
> The chief problem concerning the use of manila and sisal was to distribute rope for the most essential uses. Controls over manila and the type of rope that could be made and distributed were severe from the first. The controls on sisal were not as severe when the order was first issued—but were tightened later. . . . By the end of 1942 it was obvious that divided control was no longer effective. All fibres of different types became important in the situation. Soft fibres were being used for rope to an increasing extent and it was therefore strongly urged . . . that the responsibility for the supply and use of all fibres, excepting cotton, wool, silk and synthetics," be "placed in one department. It was on this basis that the Cordage Branch was formed."

The Cordage Branch administered the following M orders which were designed to control the use of all critical fibres and their products:

M 36—later merged into Cordage Order *M 84*

M 84 "provided controls for the use of sisal and sisal products" and was later "expanded to permit allocations and scheduling "also of manila and other cordage products." This order epitomized the *universal need* for rope throughout the war effort by listing, in the face of critically short supplies, over 400 permitted uses for rope. M 47 conserved and directed "the use of burlap to what were regarded as the most essential uses."

M 70 Controlled "the use of jute and jute products including imported products and products made from scrap jute. (Scrap jute is made up of jute bagging taken from cotton bales and burlap which has been used to the extent that it can no longer be used for bags or the manufacture of any other permitted product.)"

M 82 Provided "that hemp seed, necessary in the planting of American Hemp" could "be purchased only by the Commodity Credit Corporation."

M 138 Controlled Istle and Istle products.
M 187 Controlled Sunn Hemp and Sunn Hemp products.
M 284 Controlled flax and flax products.
M 312 Controlled coir and coir products.
M 63—a General Imports Order controlled some thirty fibres and their many products. Actions regarding these fibres were based on written policy which in turn was often based upon decisions of the Combined Raw Materials Board, Stockpiling and Transportation Division of the office of Economic Warfare.

At this point it may be well to review the actions which were taken to secure supplies of fibres necessary to insure full capacity operations of the soft fibre industry in supplying products essential for military and civilian use. In a "Joint Report by the U. S. Army and Harriman Mission" on *Jute* and Jute Goods there is this record:

> "The Jute Control became responsible for all purchases of raw jute as from October 1941 and of Jute Goods from July 1942 though prior to those dates they had purchased reserve stocks of both. Purchase of both raw Jute and Jute Goods are made through normal trade channels. With shortage of shipping from India purchase on Control Account was considered essential to ensure that purchases were made well ahead and that freight was utilized for for the most urgently needed goods in the light of information about expected needs." The spinners were allowed about three months' stock.

Two photostat negatives (121 B & C) issued May 18, 1945 are available giving A STATISTICAL SUMMARY OF THE PUBLIC PURCHASES AND STOCKS OF RAW JUTE—from prior to July 1, 1942 to January-February 1945.

It shows purchases of 480.2 million pounds in the 3 years and 2 months period; deliveries into stockpile 357.9 million pounds and releases from the stockpile of 235.8 million pounds. "Of the total 135,000,000 pounds in the Government stockpile on January 1, 1945, butts represented only about 9,000,000 pounds." Long fibre included Jute from India; Urena Lobata (known as Congo Jute) from Belgian Congo and "a negligible quantity from other sources."

Table 121C gives Total Domestic Consumption of raw Jute in those years as follows:—

1942 107,300,000 pounds;
1943 136,800,000 pounds;
1944 149,200,000 pounds; and the forecast for
1945 was 150,000,000 pounds.

At this point it seems in order to recall how promptly the jute spinning capacity of the soft fibre manufacturing industry was diverted from peacetime to essential war purposes. This can be shown by a brief examination of the uses to which United States shipments of jute yarns and roves were put during 1939 and during 1943 and 1944. The industry made an amazing shift in production from carpet yarn to vitally needed jute rope yarn.

	Shipments (in pounds)		
	1939	1943	1944
Carpet Yarn	82,086,815	2,336,661	67,562
Electric Yarn & Rove	7,466,955	16,577,651	12,868,043
Packing Rove	409,321	531,145	464,709
Rope Yarn*	131,630	45,583,755	52,179,013
Twine**	27,889,698	38,830,691	36,459,558
Miscellaneous***	7,368,931	13,117,405	13,140,434
Total	125,353,350	116,977,308	115,179,319

*Including yarn for wire rope centers. This figure also includes yarn converted directly into jute rope and wire rope centers by soft fibre spinners.

**Wholly of jute, and does not include production on soft fibre machinery of twines of mixtures of jute and other fibres.

***Including reinforced paper yarn, webbing yarn, and other weaving yarns.

Some of the end-uses for *jute fibre* products made by members of the Soft Fibre Spinning Industry during World War II as recalled by industry members of this Task Group were:—

"Jute was used as an extender with Sisal fibres for Binder Twine."

"Entirely different from World War I, World War II was highly mechanized and jute entered into this picture to a large extent as a component of electrical cables and portable telephone cables. Don't confuse the latter with telephone lines. I mean telephone trunk cables, terminals, etc. It will be remembered that in the Normandy push, the movement of gasoline was a must. This entailed the unique operation with the manufacturer of gasoline lines not only on land, but actually under the English Channel. These pipe lines were serviced on the outside with jute yarns as reinforcements, as well as for abrasive resistance over rough terrain.

Wire rope cores were in very considerable demand for vehicle haulage. Because of the temporary nature of the job, much of this requirement was made from jute centers.

Jute yarns were supplied freely for camouflage netting and also as the weft of a cloth in combination with cotton used as a substitute for osnaburgs.

I believe that the war time jute requirements for the electrical cable military use, at least for two years on end averaged over seventeen million pounds a year.

In the domestic fields, one of the large calls, of course, came for jute rope for farm purposes. These were largely for rove yarns and the demand was very heavy."

"We were never without an allocation of jute for safety fuse yarn which we spun in quantities up to 30,000 pounds per week. This was for our own consumption for the most part but also for the Coast Mfg. and Supply Co. and the National Fuse and Powder Company. It is my belief also that we supplied jute yarn for safety fuse operations in Canada and probably for our plant in Mexico. Although safety fuse is a peacetime product, it was, of course, quite essential to war effort in the mining of iron, copper, coal and other minerals. There were other uses more directly relating to military such as fuse for hand grenades, etc."

FLAX

As I stated earlier in this review, the Flax spinner members of the soft fibre manufacturing industry were requested in 1940 to make voluntary allotments of their supplies of Flax fibre, flax yarn and linen thread for national defense uses. It may be of interest to recall the amounts of these allocations of flax stocks for government requirements in 1940.

Original Allocation (Pounds)	*Required For*
500,000 pounds	Parachute Webbing
33,000 "	Linen Lacing Cord
50,000 "	Armature Twine (Signal Corps)
80,000 "	Rove Packing
100,000 "	Shot Line
6,000 "	Flare Cord
	Shoe Thread
	Miscellaneous
Total 769,000 pounds	

A careful record of government orders accepted was kept by the Institute and monthly reports were submitted to the then Textile Unit of the Office of Production Management.

A good background picture of the flax situation is found in a letter in the National Archives written by Robert T. Stevens to E. R. Stettinius, Jr. on June 24, 1940.

"The soil and climatic conditions in the Willamette Valley section of Oregon are particularly favorable for flax growing. The acreage of fibre flax has steadily increased during the past several years and the yield per acre, generally has increased along with improvement in quality. . . .

It is estimated that the present Oregon flax crop, available in November, will probably yield a production of from 500 to 600 tons up to perhaps a maximum of 1000 tons of flax fibre. *With normal foreign sources cut off*, the 500 to 600 ton Oregon crop mentioned above assumes great importance at the present time. We are definitely short of linen yarn of the quality to meet Army and Navy specifications,—particularly for parachute webbing."

Only three weeks later, July 12, 1940, Mr. Stevens sent Mr. Stettinius, Jr. the following memorandum:

> "At a conference held June 18, 1940 with Army, Navy and principal producers of linen yarns, it was estimated that the requirements of the Army and Navy upon the assumed basis of an Army of 4,000,000 men and 50,000 airplanes (36,000 Army—14,000 Navy) would be, in order of their importance, as follows:

	pounds of flax yarn
1. Parachute Webbing	1,000,000
2. Signal Corps Armature Twine	200,000
3. Rove Packing	60,000
4. Shot Line	100,000
5. Flare Cord	4,000
6. Shoe Thread:	
Army	325,000
Navy	40,000
7. Lacing Cord (training planes)	
Army	100,000
Navy	60,000
Total	1,889,000

> (The above quantities are developed using the following factors: 50,000 airplanes—4 parachutes each—200,000 parachutes. Parachute webbing 5 lbs. each x 200,000 parachutes—1,000,000 pounds lacing cord. 20 pounds per airplane x 5,000 Army—100,000 pounds; Navy—60,000 pounds.
>
> "The domestic flax spinning industry is entirely adequate to satisfy both civilian and defense requirements being only limited by the supply of raw material."

In order to increase the supplies of much needed flax fibre our Government

a) Encouraged increased production in Oregon;
b) Contracted to take flax fibre produced in a new project in Peru;
c) Secured some flax fibre from Argentine, Brazil and Chile and Canada.

Frankly, I have have not yet found the records of these arrangements in the National Archives. They may be in some Commodity Credit Corporation or Department of Agriculture historical files, although such war agencies as the Bureau of Economic Warfare and Combined Raw Materials Board, among others, must have been actively involved. Perhaps it is just as well—and less wearying to this meeting—provided my brief outline above is correct.

Later, on February 26, 1943, David L. Malcolm, Jr. Chief of the Soft Fibre Cordage Unit, Textile Clothing & Leather Division W. P. B. wrote to H. K. Fleming, Chief of the Blockade Division, B. E. W. in part as follows:

> "Our domestic flax outlook for 1943 . . . appears to be satisfactory at this time. Imports of fibre from Peru and Canada . . . are now reaching this country. In addition to this we also have a

considerable quantity of flax that we anticipate being produced in Oregon this year. At the present time this Division is engaged in drawing up recommendations for an increase in the Oregon production facilities and acreage so as to increase the over-all quantity of fibre that will be made available from this source.

The quality of Oregon flax is such that we feel that every effort should be made to increase its production *rather than to otherwise depend on inferior types of flax processed abroad.* (emphasis mine) We feel that domestic spinners will be furnished with a sufficient quantity of fibre during 1943 to permit them to maintain their present maximum capacity. On the other hand there is not sufficient flax fibre available for the formation of a government stock-pile over and above these requirements."

There is a very informative statement concerning the Flax Fibre Position attached to a memorandum dated August 18, 1943 from A. R. Howe to Courtney C. Brown, Commodity Credit Corporation, U. S. Department of Agriculture. It divides the flax supply into its three Grade Groups naming the sources and it gives the requirements in total and by grades.

The expected flax supply 7-1-43 to 12-31-44 was 20,384,000 pounds against maximum requirements for 15,000,000 pounds.

One company's participation in the flax spinning program was as follows:

"Approximately one half of our total linen product went to defense activity . . . the balance of our production of thread and twine went in large measure to sustain non-defense activity and, in great measure, could be considered essential in maintaining the civilian community in a wide range of goods and services. In reviewing the areas where our products were utilized in direct and indirect government production, we would list military footwear, aviation components, parachutes, electrical products, narrow tapes and webbings products and camouflage netting as important end items requiring our products."

Another Company briefly summarizes its war products in this category as:

"Yarns for parachute harness, fire hose, and camouflage cloth—
Threads, waxed and unwaxed for braiding, cabling and lacing.
Stitching threads for airplanes, tanks, gliders, shoes, canvas, barrage balloons, halyards and signal cords."

SOFT HEMP (Cannabis Sativa)

American Hemp was another fibre regularly grown within the United States although in quantities much less in the late thirties than in former years.

A very helpful source of information on the War Hemp Program is contained in the review given by Dr. S. H. McCrory, Director of the Hemp Division, Commodity Credit Corporation at the Hemp Conference held at Iowa State College, Ames, Iowa, June 13 and 14, 1944. I draw the following facts from Dr. McCrory's statement:

"In the spring of 1942, an order was issued freezing the supplies of hemp seed and requiring that it be sold to the Commodity Credit Corporation, and directing the planting of 36,000 acres of hemp for seed, which it was thought would produce sufficient seed to plant 300,000 acres for fibre. The remainder of the seed was to be used for hemp for fibre."

The Kentucky seed hemp crop in 1941 had been exceptionally good—but very bad fall and winter weather ruined much seed, so only 228,899 bushels were finally harvested—less than half the expected amount.

The six existing hemp mills could not produce all the fibre required.

"On September 19, 1942, Program Determination No. 70 was issued by the W.P.B. which requested the Department of Agriculture to produce 300,000 acres of hemp for fibre and 50,000 acres of hemp for seed in 1943 and provided for the erection of 71 hemp mills with funds to be provided by Defense Plant Corporation. This, with an experimental mill previously authorized, made 72 new mills. In October the Commodity Credit Corporation was instructed to proceed with the job. On October 14 the Hemp Division of the C. C. C. started work."

Estimates had to be revised downward several times due to inadequate supplies of seed-growing crops injured by bad weather—difficulty in securing an adequate supply of labor for the mills, etc.

"W.P.B. issued a directive to all cordage manufacturers requiring them on July 1, 1944, to begin using 10% of American Hemp line fibre in all cordage above ¾" diameter in all rope manufactured except cores for wire cables and well drilling cables."

In a memorandum dated October 6, 1944 from George H. Lanier, Jr., Chairman, Textile Requirements Committee to John H. Martin, Program Implementation Officer on the subject "Modification of the American Hemp Program" we find that the Hemp Division C. C. C. reported to the Cordage Branch that as of September 1944, the straw obtained from 1943 and 1944 plantings would yield 60,000,000 pounds of hemp line fibre—some 15,000,000 pounds less than was called for by Amendment No. 1 to Program Determination No. 70.

"A review of the cordage fibre supply requirements position indicates that the above quantity (60,000 lbs. of hemp line fibre) will be adequate to meet all requirements in 1945 and most of 1946. Requirements of hemp line fibre for use as extender in sisal rope are currently estimated at 5,760,000 pounds per quarter, on the basis of sisal rope requirements approved in Program Determinations No. 615 and No. 660 (Textile Requirements Decision No. 115, Amendments 3 and 5) for the third and fourth quarters of 1944 respectively. In both programs, approved requirements of sisal rope approximated 58,000,000 pounds for the quarter in question, and each program provided for the use of American Hemp as an extender."

Flax and American Hemp are two fibres produced successfully in the U. S. which the soft fibre manufacturing industry was and is capable of processing—by equipment, long experience and knowhow—into products essential for civilian and military end uses.

ISTLE

Another fibre available *overland* from Mexico was istle—the palma and pita varieties were used ordinarily for twine and cordage. This fibre could be processed either on hard or on soft fibre machinery.

In the W.P.B. Materials Handbook 115A, issued July 20, 1945 we find the following:

> "In order to more effectively conserve the supply and to channel production to meet war and essential civilian requirements, all types of istle were brought under strict government control in May 1942. Later the Defense Supplies Corporation was made the sole purchasing agent in dealing with Mexican exporting firms. A public stockpile was set up and was increased from time to time until the second quarter of 1944 when stocks tula and jaumave in this country were considered ample and the contract for their purchase was terminated. Stocks of palms and pita too were subsequently found to be in excessive supply and their storage became . . . a problem."

The Domestic Consumption of Palma and Pita Istle—largely for twine and cordage was:

14,800,000 pounds in 1942
25,300,000 pounds in 1943
21,200,000 pounds in 1944
and 7,000,000 pounds during January-April 1945.

Large quantities of Istle were used as an extender with Jute for wrapping twines and in Jute rope—by soft fibre manufacturers.

RAMIE

Some ramie was used as an extender to conserve flax fibre in the manufacture of linen thread and similar items. However, the supplies of ramie fibre were very limited, particularly after the Philippines fell into Japanese hands.

SUMMARY

This "review of the role played by the soft fibre manufacturing industry in World War II establishes, I believe, the fact that the industry was called upon for parts which it alone could play—and without which the whole military—and essential civilian programs would have been badly—if not fatally—crippled. The rope program alone proves that. And the availability of an industry which can process such indigenous fibres as Flax and Soft Hemp—as well as other western hemisphere fibres such as istle and kenaf is a valuable asset to the

United States in a world which may at any time shut off the availability of offshore fibres.

The second part of this subject poses the question of the possibilities" of a role to be played by the soft fibre manufacturing industry in a future war." And here we run into many questions. What kind of war? Will it be a small orthodox war severely contained geographically—or must we contemplate being "On the Beach" with Neville Shute? Before the industry members of this Task Group can proceed very far in their thinking as to what demands are likely to be made upon the soft fibre industry for products both military and essentially civilian "in a future war"—it is hoped that our friends from various governmental departments who are participants in the Group meetings—can properly spell out the present thinking as to the kind of war for which to be prepared.

After World War II the Soft Fibre manufacturing industry reverted to the pre-war pattern. Abaca became available for rope making with the expected decline in demand for jute rope. There was however a shortlived revival of demand for jute rope for ammunition box handles following the outbreak of war in Korea.

Changes in Carpet and Rug manufacturing have caused a shrinkage in demand for jute carpet backing yarn—the industry's largest volume production item.

One bright spot has been an accelerated demand for jute rove and yarn for the electrical cable industry—and here soft fibre industry products are still very active in the defense program of building BMEW system and other warning safeguards around the hemisphere.

Soft fibre twine business has declined drastically since the peak of war demand when, in 1946, this industry shipped 60,331,299 pounds of jute twine and 14,757,273 pounds of non-jute twine, a 75,088,572 pound total.

In 1957 domestic soft fibre twine shipments were 18,104,399 pounds of jute twine and 1,361,038 pounds of non-jute twine—a total of 19,465,437 pounds. Changing practices in packaging and substitute products are in part responsible. There is also another factor which cannot be ignored—and that is the large increase in imports of jute twines since the end of World War II.

Imports of jute twine represented only 0.17% of domestic industry shipments in 1951—whereas in 1956 imports were 17.17% of industry shipments.

The deleterious influence of low priced imports of 3,759,312 pounds of jute twine on the shrinking market is having very serious consequences in the soft fibre manufacturing industry.

There have been some mergers in recent years and a few companies have discontinued manufacturing soft fibre products. Further shrinkage is inevitable if no effective means is found to protect the domestic producers from imports of competitive goods made by workers paid only one-third to one-twelfth the wages paid in soft fibre manufacturing plants in the United States. And these imported goods are made of the same fibres processed on machinery identical to that used in this country.

If I appear guilty here of special pleading, I must insist that this question of imports has a direct bearing on the problems before this

Task Group as they relate directly to soft fibre manufacturing capacities which may be available when needed "in a future war."

It is timely that this Task Group has been created to explore the possible requirements for soft fibre products—essential for military and civilian use—in "a future war." If such products will be required it is important to consider whether the manufacturing capacity will be available to produce desired quantities, and whether adequate supplies of raw fibres can be secured. Such fibre requirements might conceivably include flax and soft hemp as well as kenaf.

Since it is understood that the possibility of some future strategic need for kenaf fibre in the United States is to be studied, I do hope the very able treatise by Charles W. Schoffstall entitled, "U. S. Kenaf Program in Relation to National Defense Planning" dated March 10, 1953 will be available for study by every person in this Soft Fibre Task Group. The principles there enunciated by Mr. Schoffstall appear to be as sound now, five and one-half years later, as they were when written.[1]

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[1]Copy of this report which is no longer "classified" can be had by writing either to Dr. Schoffstall in the U. S. Department of Commerce, Washington, D. C. or to the Secretary of the Soil and Crop Science Society of Florida. Ed.

Universal Method of Yarn Making*

Emilian Bobkowicz**

The subject of this paper is a new method of yarn making. To understand this universal method better it is well to know more about its background as well as the developments which led to these inventions and made them technically possible and economically feasible.

In times of peace and war textiles are of major importance to the economy of any country. During military emergencies textiles are second only to steel in strategic importance. To the soldier they are as basic as food because they provide clothing, shelter and protection for equipment.

The textile industry depends for many of its processes on the use of fibers of widely different kinds. In the past natural fibers comprised the only source of supply to meet the needs.

For about two decades, however, man-made fibers have been making evergrowing inroads into this field mainly in specialized areas, whereas paper and plastics are succeeding in many traditional textile markets of the low price bracket.

In this struggle between natural and synthetic fibers a major role is being played by chemical research directed towards improvements with special emphasis on the increase of the usefulness of fibers, their end use products and the lowering of both production and processing costs.

Natural fibers and synthetics and their end use products benefited from the improvements in functional properties and production economy. However, the gains made by synthetics have been far more spectatular than those of natural fibers.

Yet natural fibers, such as cotton, ramie a.s.o. are unquestionably still the most versatile fibers known to man thanks to their superior and complex structure engineered by nature, a structure not yet approached even by "miracle" synthetics. The fate of the future of natural fibers now seems to depend almost entirely upon whether and to what extent research will succeed in reducing production and processing costs and in matching synthetics in some of the more spectacular functional properties of the latter, among them "wash and wear."

However, there is always the danger, even though a seemingly remote one, that the chemical industry may some day succeed in developing synthetics of as versatile or even better qualities than natural

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*NOTE: At the time this paper was scheduled on the program it was the thought and plan that yarn samples prepared with the pilot unit that is described would be on display for examination and testing at the time of the meeting in St. Petersburg. A number of different fiber samples in sliver form were rushed to Mr. Bobkowicz for this purpose. As this phase of the Proceedings goes to press quite some time after the meeting no materials have been received. For any information or samples pertaining to this work it is respectfully requested that the interested party write directly to the author for same at his Montreal address. —Ed.

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fibers at lower prices. Amazingly enough, however, the same technological progress of the chemical industry responsible for the tremendous success of synthetic fibers and plastics, the principal competitors of natural fibers, is providing the basic approach which may become the most valuable benefactor to natural fibers in their struggle against synthetics and plastics.

This idea of joining instead of fighting the competitor is opening up rather promising new vistas for radically new concepts in technological methods and means of textile fiber processing into yarn and end use products as well as in the improvement of their functional properties. The trend toward a union between textiles and chemistry can already be found all the way from fertilizers for fiber crops to the finished textiles. At every stage the chemist is being called on to aid the fiber producer, spinner, weaver and convertor, if he is not already deeply involved in the production of synthetic fibers, plastic resins and films.

Conventional textile fiber processing is, for instance, facing a revolutionary challenge in the form of non-woven fabric production, which is considered the only really new development in the textile industry since mechanical textile fiber processing began. Basically, non-woven fabrics are produced by forming a web of one or more at random, cross or parallel arranged fiber layers, bonded together by a plastic bonding agent, thus entirely omitting conventional textile operations of forming a yarn and weaving or knitting the yarn into a fabric. The production of non-woven fabrics is growing rapidly and the present annual production of 70 million pounds is expected to double annually during the next few years. However, non-woven fabrics as yet lack the strength, hand, appearance, wear and breeze of conventional cloth. This sets limitations in their end use. With the development of still better and cheaper bonding agents and improvement of production methods, non-woven fabrics may considerably extend their use in many new fields. A non-woven fabric is a typical product of the growing interdependence between the textile and chemical industries.

We are indebted to these developments for the production of a wide range of synthetic fibers, resins and films, many with remarkable new properties which have made it possible to develop many basic changes in the method of yarn making. To understand this new method better it is necessary to become more specific.

Conventional spinning is usually considered to include various preparatory and cleaning processes such as the opening and cleaning of the fiber stock, picking, carding, combing, drawing and roving in addition to the actual twisting-spinning of the yarn. While passing through these steps of processing the fibers are successively called "lap," "sliver," "roving" and finally "yarn."

Since the time of Adam and Eve there has been no basic change in the art of making yarn which is still based upon the cohesion principle. Fibers are capable of formation into yarn by reason of their friction against each other and a consequent resistance to lengthwise slippage. The effectiveness of this frictional grip depends upon the nature of the fiber surface and the pressure between fibers due to twist.

Thus the property of a staple fiber which aids in its spinning is essentially its natural friction characteristics, its clinging or holding together in a loose mass. The finer and longer the fibers, the greater the number of fiber-to-fiber contacts, the greater the resistance to slippage of the fibers, the better their spinnability and the greater the strength of the yarn. Microscopic analysis of the structure of a conventional yarn demonstrates that staple fibers are not in contact over a considerable length of the fibers, but at more or less isolated points. To increase the number of contact points and to prevent slippage twist must be applied to the fiber strand to form the conventional yarn.

Because this adherence on which the spinner depends is slight, the fibers must be carried gradually and slowly through the many previously mentioned stages to evolve the final yarn. This is the laborious, slow, complex and costly conventional spinning process with the result that the cost of the raw material in a yarn often represents but a fraction of the yarn price, particularly in the medium and high count range, with processing costs as a major component.

The entirely new yarn making concept discussed in this paper is based on the adhesion and heat welding forces of thermoplastic bonding agents which greatly amplify the cohesive forces that are desired. The principal difference between the conventional and the new method is that the first is based upon a physical and the second on a chemical process.

The basic principles of this new yarn making process comprise a sequence of operations wherein one or more layers of relatively thin and even staple fiber fleeces are heat laminated to one or both sides of a thermoplastic film to form a non-woven, sandwich-like, continuous fibertape of bonded fibers in parallel arrangement. This is then slit into a predetermined number of narrow ribbons each of which is twisted into yarn and heatlocked. In this new chemical process of forming a yarn the frictional properties of fibers as well as their length naturally are of much less importance. The bonding forces and the basic properties of the bonding agent will become the decisive factors which will govern the strength of the yarn in addition to the inherent strength of the fibers used. In this new type of yarn, in contrast to the conventional yarn, the fibers are in complete contact between each other, strongly welded together by the adhesive action of the bonding agent, which may be of any of the materials from which standard or "miracle" synthetics or plastic films are made. Consequently, due to the added strength factors in this new type of yarn, the need for high twist and ply yarns, the means to improve the strength by increased frictional grip, may become of less importance and lead to increased yields per spindle hour without loss in strength.

Depending upon the choice of the fibers or their blends and the type of the bonding agent, a yarn of desired combined functional and chemical properties of both materials can be tailor-made to suit almost any requirement, quality—as well as pricewise. Staple fibers which lack adequate natural frictional properties or are too stiff and/or too short to be economically formed by the conventional method of spinning into an adequately strong yarn of satisfactory properties and appearance will not encounter such handicaps any more when

spun by the new method. This will result in a considerable upgrading in the spinnability and usefulness of many fibers, short or long, particularly however of the hard to handle bast and hard fibers as well as regenerated fibers, linters and waste. This and the much lower waste percentage of the new process will become a new and important factor of economy in the future production of yarns.

Sisal and henequen for example, both strong and bright fibers, could find many uses if it were not for their low frictional properties and stiffness which do not permit their use in a medium count yarn for industrial and other weaves. Sisal bags in their present construction are unsatisfactory since they are too heavy and have too rough a hand. The yarn has a tendency to untwist and any break of it in a bag will rapidly open up the latter and make it useless as a container. The new spinning method under discussion will overcome all these obstacles and make it possible to produce a cheaper and much lighter and smoother yarn of strongly welded fibers with no possibility of untwisting. A bag from such yarn will be considerably lighter in weight, yet strong enough to meet all the requirements of a superior bag. It also will have a much better appearance than a conventional jute or sisal bag and be of greater reuse value as well. The difference in price between raw jute and henequen is now about 4-6 cents per pound in favor of henequen. The lower processing costs of the cheaper fiber will offset the additional cost of the bonding agent without taking into consideration that the superior quality of the yarn will also upgrade its market value and usefulness for many other end uses, where higher priced yarns are now necessary.

Ramie's wider commercial use is, for instance, limited only by the fact that its spinning into yarn by conventional methods is too costly and complex in spite of its being nature's "miracle fiber" whose versatile and superior properties are yet unmatched by any synthetic. There are in the world only a limited number of highly specialized spinning mills which are processing ramie efficiently and successfully into various types of yarn and other products. All of these mills are located abroad, in the Far East and Europe, with none in North America. The new yarn making process will eliminate these obstacles entirely because with little "know-how" and small investment all the ramie produced in Florida can easily be processed right in Florida into various types of high class yarns, which in quality and price will meet all the requirements of the consumer market. A ramie yarn, for instance, made from degummed and bleached ramie staple fibers, welded together by a nylon or dacron type bonding agent will have the properties of both and thus be superior to any yarn on the market though still be competitive.

A standard yarn making machine of this universal type embodies 20 to 40 special spindles and other special devices for heatsealing with thermostatic controls for forming a continuous non-woven type, sandwich-like, laminated fibertape of the desired width, thickness, fiber density and amount of the bonding agent, for slitting said fibertape into the desired number of narrow ribbons of predetermined width, for heatlocking and imparting into these ribbons the desired amount of twist at spindle speeds of 10-15000 RPM or even higher, for simultaneously collecting the ready yarn into large commercial

yarn packages and for easy or even automatic doffing of said yarn packages.

A special spindle had to be developed for this machine because none of the conventional types could meet all the requirements found necessary in this new process.

This method of yarn making thus provides a short cut in the processing which will result in substantial economies in equipment, space and production costs as well as reduction in waste. This is because the costly and complex equipment and processes of drawing and roving will be entirely eliminated with a simultaneously increased efficiency of the spindles.

The raw material preferred for this universal yarn making machine is one or more card slivers of substantially parallel fibers of any desired type and one or more thin thermoplastic films for use as a bonding agent. The slivers and film are simultaneously fed into the machine which, in a continuous sequence of operations briefly described above, are transformed into large size packages of the desired count of yarn.

If preferred, non-woven type fibertapes prefabricated elsewhere can be fed into the machine which will slit and transform it into yarn as described above. In either case the composition, thickness, width of the narrow ribbons and imparted amount of twist will govern the count, type and properties of the yarn.

In the processing of bast fibers, for instance, the 40" diameter and 5" wide standard sliver rolls of a high output braker—finisher card could be processed as above described, directly into any desired type of yarn.

To further economize, the sliver of such card easily could be transformed by an inexpensive laminating attachment into one or more continuous, non-woven laminated fibertapes in the form of large rolls 5 to 10 inches in diameter, each of which again could be processed into a plurality of yarns on the same universal yarn making machine. Obviously such fibersliver or laminated tape rolls could quite conveniently become standard articles of trade for fiber growing countries that would result in substantial additional savings by elimination of the conventional baling, pressing, opening and other fiber preparations before carding, all of which add substantially to overall cost of the finished commodity at any stage. This leaves just one step in yarn processing from such material thru the use of the universal spinning procedure.

The simplicity of this processing method, the substantial savings that result and the marketing possibilities of such rolls for processing on the Universal yarn making machine will sooner or later lead to mass production of standard types of card sliver rolls or maybe even non-woven fibertapes at or near fiber producing centers.

By way of summary some of the main features and advantages of the new process over the conventional method of making yarn are as follows:

UNIVERSAL: Staple fibers of any variety and origin, of any frictional properties and almost any length can be economically processed into yarn and twine of any desired amount of twist.

VERSATILE: A wide range of blends of fibers of any type is possible due to the sandwich-like composition of the ribbons twisted into yarn. By proper selection of the fibers of each fiber layer and of the type of the imparted bonding agent yarns of desired properties, texture and appearance can be tailor made.

COMPACT: Each of the universal, multiple-spindle, yarn-making machines comprise a complete, integrated, compact yarn making unit for processing of any type of fiber slivers or non-woven fiber-tapes in a continuous sequence of operations into yarn, in the form of large size commercial packages ready for marketing.

EFFICIENT: The new yarn making machine is highly efficient with yields per spindle hour, particularly in the production of medium and coarse yarns, several times higher than those of conventional machines.

SIMPLE: Little or almost no experience or "know-how" of the complex conventional technique of spinning is required to produce yarns by the new method and its means.

ECONOMIC: By entirely eliminating the costly equipment and complex drawing and roving operations of the conventional spinning process substantial economies in the cost of yarn production are possible. It facilitates, with considerably less space and investment, hitherto uneconomical, small scale yarn production of a versatile assortment of counts and variety of yarns, essential to meet ever changing demands due to seasonal and styling factors.

A pilot unit of the new method and means has recently been completed. Extensive tests with a wide range of fibers and variety of blends as well as thermoplastic bonding agents will ascertain all the possibilities and limitations of this new development in yarn making. This will enable proper evaluation of the method, means as well as yarns, by comparing them with the conventional procedure and product.

The developments in the production of the new type of yarns with a thermoplastic bonding agent also prepared the way for a new concept in the production of an improved non-woven fabric. This is made up of two or more layers of this type of yarn arranged crosswise, successively, to form a weave-like non-woven fabric by heat treatment and compression. This NON-WOVEN YARN FABRIC in contrast to the hitherto known NON-WOVEN FIBER FABRIC, has distinct advantages over the latter by its close resemblance to the texture, appearance, breeze, hand and other properties of a conventional weave made on a loom with interlaced yarns. The new non-woven yarn fabric process entirely eliminates the complex and slow weaving operations while its novel mechanical means will enable continuous production at high speed. This process is still in the development stage and it will take some time before its application in production.

The economies and implications of the novel yarn making and non-woven yarn fabric concept will no doubt be subject to the most searching scrutiny by the textile fiber producing and processing in-

dustries, which will be faced with the need for rethinking the whole cycle in terms of the new developments. The details of this new spinning method as well as those of the manner of producing this new type of non-woven fabric are shown diagramatically in sketches published elsewhere, copy of which can be had upon request of the author.

The Place of Non-Woody Natural Fibers in Papermaking

THOMAS S. CHAMBERS*

Ladies and gentlemen of the Soil and Crop Science Society, and distinguished visitors:

It is a privilege and an honor to have been asked to appear before you. I would like publicly to express my appreciation to your program committee for their suggestion last May that I might participate in your program, especially when to the invitation was coupled the statement that they would leave the choice of subject to me. After reflecting on possible subjects in which I would be competent to address you, I suggested that we schedule some remarks on The Place of Non-Woody Natural Fibers in Papermaking.

In proposing this subject, I did so with five circumstances in mind:

First, it is a field where I am personally on familiar ground, with fourteen years experience as technical executive and consultant.

Secondly, paper is coming to be used so universally that interest in it is almost universal.

Thirdly, despite this widespread interest, the paper industry is often not well understood by those not working directly in it, as is often true of technical subjects.

Fourthly, paper is for the most part made from natural fibers where soil science and crop science have important contributions to make.

and *Fifthly*, while paper is made mostly from wood, there are types of papers and geographical situations where non-woody fibers of interest to you may actually be the preferred paper-making base.

There is a well-known proverb which contends that the longest way round is sometimes the shortest way home, and with this in mind I would like to make a few observations as to why wood is used for papermaking in larger volume than all other fibrous raw materials combined.

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*Thomas S. Chambers, Ph.D., Chemist and Consultant, 2666 East 73rd Street, Chicago 49, Illinois.

NOTE:—The Program Committee felt very fortunate upon finding that Dr. Chambers would be willing to arrange his far-flung and ever-busy work schedule in such a way as to meet with us and initiate the discussion of paper technology on our forum. The first thought was to develop something of a symposium on the subject but time and the newness of this field to the Society caused it to give way to the broad-guage discussion of a very important segment of the paper industry with important agricultural overtones which he has given us in such a splendid manner. In view of the interest shown in the subject at the time of its presentation and the questions that have been raised since that time it is the feeling that the Society, thru the good efforts of Dr. Chambers, has entered upon a new and very important area of study and discussion.—Ed.

Let's begin with some history. Papermaking is an ancient art. No one is sure where and when it started, but one story says that the art was first practiced by some monks in the Orient about 600 A.D., probably using bast fibers. In 1950 I had the privilege of making a field study of Oriental papermaking fibers and procedures in the Far East, and in rural areas observed papermaking by hand using methods which were probably not much different in principle from those used by the ancient practitioners of the art.

For centuries paper was made from non-woody fibers, usually from bast fibers, leaf fibers and seedhair fibers. Linen and cotton rags came to be preferred raw materials, with cereal straws used in volume for the cheaper grades of paper and board. In 1879, for example, only about 4% of the fiber used in the United States paper industry came from wood, with about 36% from rags and 44% from straw. Toward the end of the last century the proportion of wood pulp rose rapidly to half, and continued to rise so that at present it is not far from 95%. There is no question that wood pulp is by all odds the dominant raw material in the United States paper industry.

The single most important reason for the relative decline in the use of rags and straw was the tremendous growth in the tonnage of paper and paperboard produced. In 1879 less than half a million tons were made in the United States. By 1955, production crossed thirty million tons, and it is going up at an average rate of something like 3.5-4% per year. Wood substance is the only papermaking raw material available in sufficient volume to meet these tonnage demands at low cost, at regular intervals independent of seasonal harvesting and with primary value instead of waste or residual value.

It may be helpful to illustrate these advantages of wood by contrasting them briefly with some other fibers used for papermaking in smaller volume.

First, *cost*: Wood pulp is worth, in the open market, about 4¢-8¢ per pound, depending on the type of pulp. Cotton, for example, at over 30¢ is clearly non-competitive.

Second, *availability at regular intervals*: Pulpwood can be cut throughout the year, with minor limitations. Annual fiber crops, on the other hand, are harvested only once or twice in the temperate zone. Storing enough fiber to make 30,000,000 tons of paper until the next harvest came along would create a major inventory problem.

Third, *primary value instead of waste or residual value*: It would be economically impractical for a manufacturing industry with an annual production of over 30,000,000 tons and a product value of several billion dollars to be based on raw materials like cereal straws which owe their existence to the fact that they are residues left over after the primary product has been removed, in this case kernels of grain.

This point is illustrated in a small but interesting way by the early history of papermaking in California. A recent article in Paper Trade Journal noted that the California paper industry, in the pre-wood pulp days of the nineteenth century, was originally based on cereal straws; but as the agricultural economy of the state shifted from

cereal to fruit, the main raw material for the mills vanished and the mills themselves either went out of business or turned to materials like rags which were available in smaller volume.

Now I would like to mention two more reasons for the dominance of wood pulp in the tonnage paper industry, in addition to the logistic and economic reasons we have just examined. It is very important that wood pulp has chemical and physical properties which are useful enough and varied enough to enable them to serve as raw material for a tremendous variety of papers. This versatility of wood is partly due to the existence of different species in which the cellulose fibers and associated chemicals have different structures and compositions, and partly to the development of several ways of treating the wood substance to prepare it for papermaking.

The last subject regarding wood which I would like to mention before moving on to non-woody fibers is that of momentum. Because wood has become established as the prime raw material for the paper industry, there are major pressures favoring its continuation in this role. This is true with respect to research as well as economics. While the paper industry has not been as active in chemical research as some other industries, like chemicals and petroleum, one can see from the past and predict for the future that the growing body of technical knowledge about wood-based papers will continue to open new markets for them.

Now let us turn to the status and future for non-woody natural fibers in the paper industry.

You may have noted that up to this point I have made frequent reference to tonnage papers, meaning by this term papers and paperboards which are produced in large volume, like newsprint, kraft wrapping paper and container board. There is another segment of the paper industry which is concerned with products sold in lower volume at higher prices, and usually meeting end use specifications which are specialized and quite different from those met by the tonnage products. The trade classifications used in the industry for these products are somewhat arbitrary and not fully descriptive. Most of the papers I have in mind belong in the trade groups called fine papers, industrial papers and specialty papers. A few examples are currency paper, cigarette paper, some electrical papers, many filter papers and many papers used as impregnating bases for resins which are then cured to make panels like those used in plastic table tops.

For many of these specialty papers, with rigid end use requirements, wood pulps are not technically suited, and the advantages of wood for tonnage papers with respect to supply and price are not particularly important.

One of nature's great gifts to the papermaker is the occurrence of cellulose in many diverse circumstances in wood and in many other plants. The basic chemical units of which cellulose fibers are composed have a common composition and perhaps a common physiological origin, but the degree of polymerization varies, the physical structure of the cell or ultimate fiber varies and the chemicals with which the cellulose is associated vary. I am sure this is well known to all of you.

Many of the varying properties found in natural cellulose fibers

from different plants are important to the papermaker. I would like to describe a few examples for you.

1. Fiber length is important in many ways. It contributes to some of the strength properties of the sheet, and it affects the way the pulp behaves on the paper machine. Among woody fibers, length can vary from about 1 mm for some hardwoods to 3-5 mm for some softwoods. For special papers requiring longer fibers, one must look to certain of the non-woody plants. Digested abaca, for example, finds use because of the unusual length and fineness of its ultimate fiber, as well as for other properties.

2. Some papers, like currency paper, require unusual durability in handling. In addition to tensile and tear strength, they must have abrasion resistance, and stand up under creasing and crumpling. Cotton fibers (seedhair, not linters) are well adapted for these requirements.

3. Cigarette paper must meet several specifications, some of which are quite unusual. Among the unusual properties are taste characteristics when burned and controlled rate of combustion. Uniform caliper and freedom from pinholes are important. Seed flax tow has proved more satisfactory than wood pulps for the manufacture of cigarette paper. Uniform caliper, freedom from pinholes and high strength are frequently required in electrical papers and, somewhat less critically, in carbonizing tissues. Flax and abaca have found use for some grades in these product groups.

4. Filter papers, and papers used for resin impregnation, must be porous and easily wettable, among other properties. Cotton linters, which are quite different in papermaking properties from cotton seedhairs, are often used for superior filter and impregnating papers. An interesting material occasionally used in these structures is redwood bark fiber.

As papermaking technology develops through research, and as papers are able to meet more and more specialized engineering requirements, I think it is safe to predict that there will be a growing market for natural cellulose fibers with unusual papermaking characteristics. To find those markets, close cooperation will be necessary between the ultimate consumer, the specialty papermaker, and those of you who are concerned with crop science.

Now a brief word about the relationship between non-woody natural fibers and synthetic fibers. Concern is sometimes voiced about the future of specialty natural fibers in the paper industry because of the progress in development of synthetic fibers. For a limited number of specialty papermaking applications, synthetic fibers have already found a place, and they will undoubtedly find more places. But for two reasons it seems unlikely that synthetic fibers will become dominant, at least in the foreseeable future. One reason is cost. Natural fibers as high as 20¢ to 50¢ per pound (delivered to the beater) are cheaper than most synthetics, with the exception of synthetic wastes, some regenerated celluloses (like rayon) and certain types of fibrous glass.

The other reason is the combination of physical and papermaking properties with which many of the natural fibers are endowed. Some

of the synthetics are superior in individual respects, like nylon in toughness or work of rupture, but we do not yet have evidence that synthetic fibers can be manufactured with an aggregate of papermaking properties which would enable them to displace the non-woody natural fibers on a major scale. I suspect that as the engineered paper specialties grow in volume, the synthetics and the non-woody celluloses will be more likely to complement each other than to displace each other. It may be instructive to return for a moment to the historical statistics we looked at on the proportions of woody and non-woody fibers used in 1879 and today. While the *proportion* of non-woody fibers has gone down sharply, the actual tonnage now used is almost twice that of 1879. Even if synthetics were to grow faster than natural fibers on a relative basis, there appears room for attractive volumes of the agricultural products.

It is important to recognize that the natural fibers can benefit from research, just as the synthetic fibers can. A significant area for research on natural papermaking fibers lies in the improvement of fiber properties and economics by the application of plant genetics. This is true of both woody and non-woody fibers. It may be that genetic progress on the non-woody fibers can come faster than with woods; partly because the non-woody plants usually have a shorter life cycle, and partly because some of the non-woody fibers now used for papermaking, like cotton and abaca, have been bred for textile or cordage purposes. It even seems possible that genetic variants superior to the present commercial varieties for papermaking have been discarded as unsuited for textile or cordage uses. I have personally conducted a project on a specialty papermaking fiber where the proper choice of plant strain resulted in a threefold increase in acreage yield, as well as other improved characteristics. I do not think there is much doubt that genetic work directed toward papermaking applications can broaden the use of non-woody fibers in the paper industry.

We have looked briefly at non-woody natural fibers in specialty papers. We saw earlier that the non-woody fibers are under some serious disadvantages in serving tonnage markets like newsprint, wrapping paper and container board in the United States. Are these disadvantages of equal weight everywhere else? Probably not. The per capita consumption of paper in the United States is well over 400 pounds per year, and in a long-term rising trend. Huge portions of the world's population use only a fraction as much paper per capita as we do. Paper consumption appears to be related to industrial development and to living standards. As these advance abroad, the production of paper is almost certain to increase.

But some countries do not have enough timber to support a major paper industry; or if they have timber, like tropical hardwoods, other kinds of fiber are needed for blending to make a variety of papers on modern equipment. One source of pulp or paper is, of course, by export from the areas which have pulp-wood of the right kinds. While exports from the United States are increasing, shipping costs and monetary problems appear likely to increase the pressures for paper production abroad from local raw materials.

Bamboo is used by the Indian paper industry, as well as by a new

mill in Formosa, and elsewhere. While perhaps not exactly a non-woody fiber in one sense, bamboo is enough of a departure from our gymnosperm and angiosperm fiber sources to illustrate the point. Papers made at least in part from sugarcane bagasse are in production. An important part of the Japanese paper industry is based on non-woody raw materials.

I would like to forecast that the use of non-woody fibers for papermaking abroad will grow, but subject to the interplay of a complex set of factors. Perhaps the easiest way to sum them up is to say that the available, volume, cost and technical characteristics of the non-woody fibers will have to balance favorably against the increasing tonnage of paper required and the cost (or political aspects) of importing pulp or paper from pulpwood countries. This point of view is broad enough to include what I think is one of the most attractive prospects for non-woody fibers in tonnage papermaking: the local culture, abroad, of long-fibered blending agents for upgrading the manufacturing and product properties of short-fibered stocks like the hardwoods and the agricultural residues like cereal straws and bagasse. This subject has not required much attention in North America and Northern Europe, where long-fibered woods are in relatively good supply, but I think it will become important in countries where paper consumption is increasing, but where the major sources of fiber, whether woody or non-woody, are mostly short-fibered.

Now I am sure you have heard enough about paper for this time, and I will bring these remarks to a close.

SYMPOSIUM—PRODUCTION AND PROCESSING HARD LEAF FIBERS.

Abaca—World Production and Supply

Spencer H. Brewster*

I have been asked to present my views on the production of Abaca world wide, and I presume along with this, was the inference that some conclusions should be drawn from the trends which I shall outline.

A quick look at the major sources for abaca certainly indicates a downward trend in the overall production. The Philippines, who are responsible for the major portion of the production are experiencing a severe downward trend. The Central American production which was instituted as a wartime emergency measure has served its purpose, and these plantations are now producing only about 4% to 5% of the world supply. The Indonesian political problems have resulted in the extinction of Abaca production on that front and, whereas, the world is now receiving a small trickle, it is expected that even this will soon dry up. The only producing area which is showing growth is Borneo. At this writing, Borneo accounts for about 3% of the world supply, and perhaps if the other areas continue to shrink, the Borneo producers will find it profitable to continue to expand. Any study of this sort related strictly to Abaca must, of course, center about the Philippine Islands, who in effect now enjoy a relative monopoly on this commodity.

Prior to World War II, the Philippines produced 98% of the total Abaca which the world consumed. During the 1950's, this percentage has been as small as 84 and as high as 95. During 1958, it is estimated that it will be 93. Just one more short group of statistics to outline the playing field. The production of Abaca prewar was approximately 168,000 tons per annum, and during the 1950's again it has reached a low point of 110,000 tons and a high point of 132,000 tons, all of this time being well below the totals realized in the pre-world-war era.

It is my estimate, that in 1958 we will see a new low. This will undoubtedly come out between 95,000 and 100,000 tons. This is partially due to the shrinkage in Indonesia and Central America, but primarily due to a great fall-off in Philippine production.

Now let us examine the reasons why the production is off in the Philippines. I think it is general practice in the trade to separate the Philippine production into two major categories, namely, Davao and Non Davao. Historically, a little less than one-half of the Philippine

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Note: Due to Mr. Brewster's inability to attend the meeting, Mr. Clarke Cassidy, Product Techniques, Inc., Hudson, Ohio, very kindly presented his paper.

fiber has been produced in the Davao area. In the mid 50's, Davao attained a more prominent position producing more than one-half of the Philippine fiber. This was due to a climb in Davao balings and decreased balings in Non Davao areas. Commencing in 1955, the Non Davao area showed a marked increase spurred by good prices and good demand. The high price maintained the Davao production at a fairly constant level through 1956, and since that time we have seen a steady preciptious fall-off in the production in Davao. This trend has not yet ceased, and where the bottom is, no one can, at this point, hazard a guess. The present position, based on the past twelve months experience indicates the Davao area is producing only 25% of the total. The fall-off in Davao production can be attributed to several factors, the most widely publicized of these is the presence of the mosaic disease in South Mindanao. The natives in this area are fond of corn, and consequently corn production is widespread, and often interspersed with Abaca plants on the same plot of land. It has been determined that corn provides the host for the mosaic disease, and consequently the production of corn and Abaca on the same lot is a losing proposition as far as Abaca is concerned. The food supply in the Philippines is always tight, and therefore, the natives given a choice between producing Abaca which takes twenty-four months to mature and producing corn which takes 90 days to mature, and for which he knows he can find a ready market, the native will almost invariably choose the corn. For his long range security, he can plant a few cocoanut trees which require little or no care and in the South Mindanao area there is no disease affecting the cocoanut trees. Here again, the copra market is a steady one and profitable, so he has another alternative other than Abaca for his land. Some individuals who are well versed in Abaca production predict that, within two years Davao fiber will be a thing of the past. This prediction does not include the decorticated fiber which is raised on a plantation basis under good management making it possible to control the mosaic disease through the eradication of affected plants.

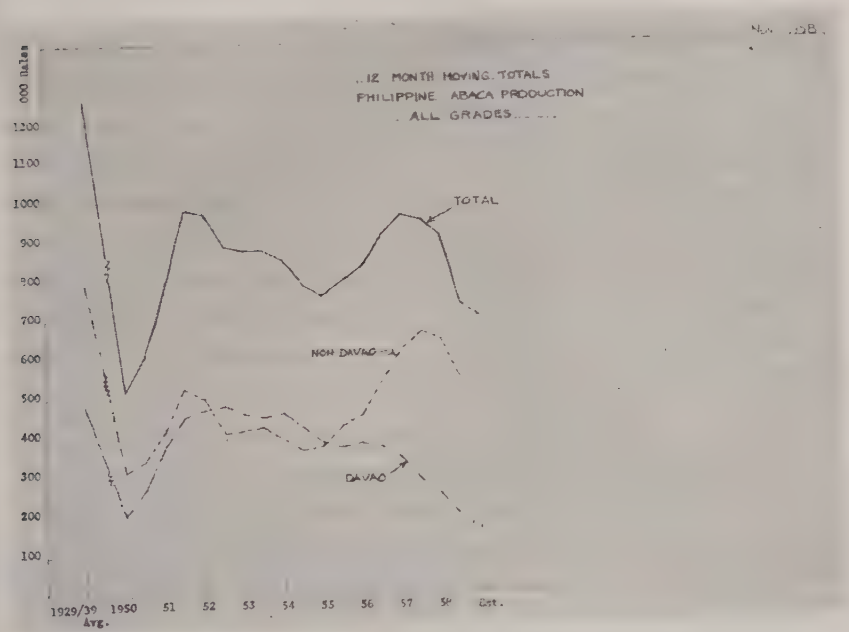
Strangely enough, in the Non Davao areas in the provinces of Leyte, Samar, Camarines, Albay, etc., we have a somewhat opposite situation. Here much of the land is suitable for growing rice, and this grain serves as the staple for the diet of the natives in the area. Here also, there is a disease rampant in the cocoanut plantations which has all but eliminated the copra production. Abaca, therefore, serves as a cash crop and in many instances grows despite the lack of scientific farming methods as we know them, since the mosaic disease is unknown in the Non Davao area. Favorable market prices have pushed the Non Davao fiber production to 75% of the Philippine total. It is expected that this percentage will grow as Davao shrinks.

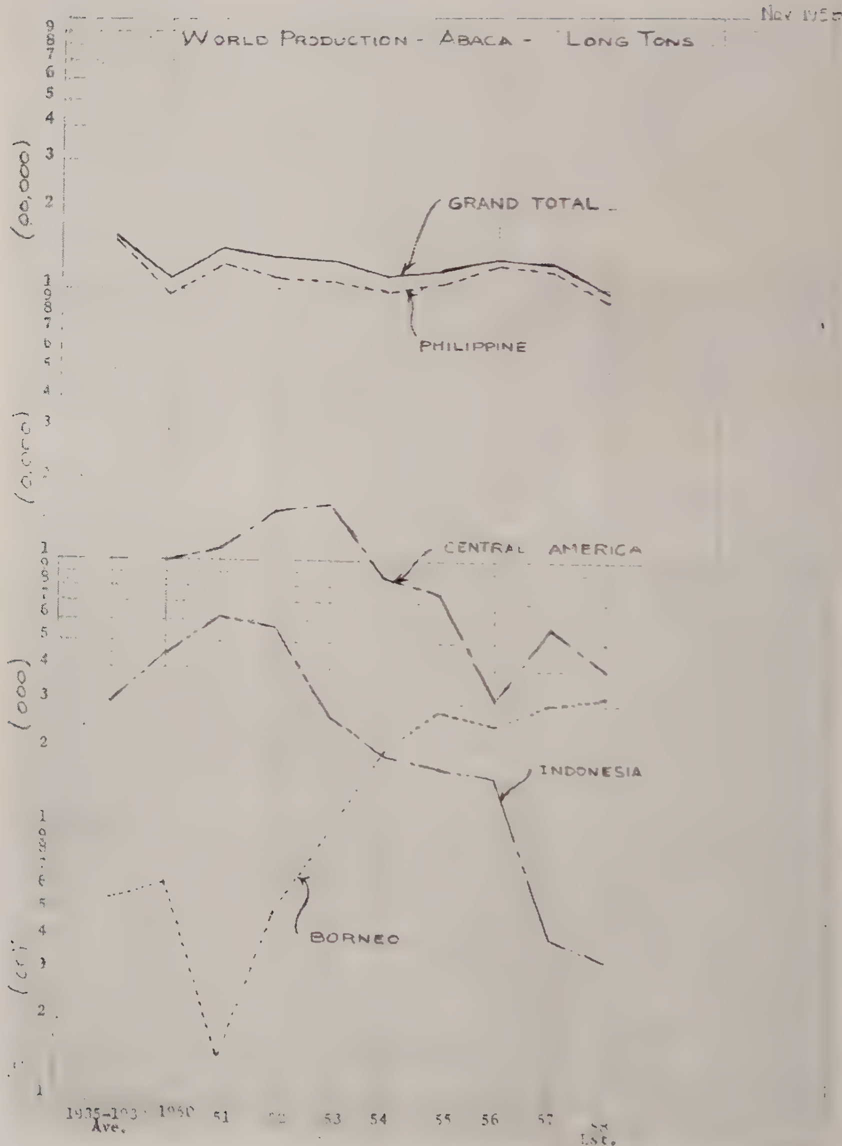
While the consuming markets for Abaca consider the price of raw fiber to be high comparing it to sisal, the producers in the Philippines, faced with inflation, soft currency and increased cost of living do not share the belief of the spinners. The Republic of the Philippines is attempting to make rapid steps towards industrialization and are indeed progressing in this respect. One can easily sit 10,000 or 12,000 miles away and solve the problems of another's economy, but it seems

to me there will be little prospect of stabilizing the Abaca industry until the Philippine Government more actively pursues a policy of developing its natural reserves. No one who has visited the Philippines can come away without the feeling that its fertile soil and pleasant climate are the basis for what should be a very strong agrarian economy.

The down trend in production has, of course, lent strength to the selling price of Abaca. Time does not permit me to explore the ramifications of where this may lead, but suffice to say, that Abaca is opposed on one side by very low priced sisal and on the other side by a great number of synthetics which are readily available. These factors should prevent run away prices for the natural fibers, even though today, Abaca production is only 58% of the prewar total. This quantity, considering the ready availability of synthetics and sisal may be perfectly adequate to meet the world's needs.

For quick reference, I have attached two charts, one showing the Philippine balings in total and then split between Davao and Non Davao producing areas, the other, showing the trend in world Abaca supply by the individual producing countries.




Nov 1958
WORLD PRODUCTION - ABACA - LONG TONS
(00,000)
GRAND TOTAL
PHILIPPINE
CENTRAL AMERICA
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INDONESIA
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1935-193 Ave.
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51
53
54
55
56
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Sisal and Henequen—World Production and Supply

B. T. Holman*

As most of you doubtless know both henequen (Agave fourcroydes) and sisal (Agave sisalana) are indigenous to southern Mexico and Central America (Yucatan). When the Spaniards conquered Yucatan in 1514, the Maya Indians were using henequen fiber in the fabrication of sandals, cordage and textiles. The first record of the fiber in commerce was in 1780 when shipments were made from Yucatan to Vera Cruz and Havana. The name sisal comes from the Yucatan port of Sisal (now abandoned) through which the fiber was first exported commercially.

Of the two agaves, sisalana or sisal is considered superior to henequen. Sisal fiber has a longer average length, it is considered to be some 30% stronger and usually has a higher color than henequen. In the field the sisal plant is distinguished from henequen by its dark green color, henequen being of bluish-green, and the absence of lateral spines on the leaves. Sisal also appears to require better soil and climatic conditions.

Agave fiber was introduced to the United States by a man of the name of Perrine who in the early 1800's was American consul in the town of Campeche in the Yucatan peninsula. In 1836 in the belief that the agaves could be grown profitably in the United States he shipped plants of both fourcroydes and sisalana to Florida. The present sisal industry owes its existence to the plants that Perrine shipped to Florida as Mexico later prohibited the exportation of all agave planting material. Despite this prohibition the agaves continued to spread.

In 1891 a German by the name of Dr. Richard Heindorf arrived in Tanga, in what was then German East Africa but is known today as Tanganyika. He was searching for some plant that could be exploited commercially on the rather dry plains near Tanga. In the Kew Garden Bulletin of February, 1892 he found an article referring to Mexican sisal which plant he thought would be the answer to his problem. On investigating further he found that the export of sisal planting material had been forbidden by the Mexican government. The Kew Bulletin however mentioned Perrine's shipment of agaves to Florida so he wrote the firm of Reasoner Brothers, plant dealers in Florida, and had 1,000 plants of agave sisalana shipped to him in Hamburg, Germany. Of this lot 80% were dead on arrival and the balance of 200 pieces were reshipped to Tanga where they arrived in good condition. Only 62 of the plants survived the replanting and they were the basis of the present day African sisal industry. In 1907

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*International Harvester Company, Chicago, Ill.

Note: Due to Mr. Holman's inability to attend the meeting his paper was presented by D. W. Fishler, U. S. Dept. Agr. Cordage Fiber Section, Belle Glade, Fla.

planting material was supplied to Kenya Colony to establish the industry there. A small industry was likewise established in Uganda. Sisal eventually spread to Portuguese Africa, Mozambique and Madagascar. After the end of World War II Dr. Heindorf was found living in poverty in Berlin by Sir Eldred Hitchcock of the Tanganyika Sisal Marketing Association. From then until he died in 1954 at the age of 90 Dr. Heindorf was supported by funds from the Tanganyika Sisal Growers Association.

Propagation of sisal, a clone, is usually done by bulbils, the small buds developed in the axils of the flower after flowering takes place. These buds develop into small plants. As many as 4,000 are found on one plant. The bulbils are knocked off and placed in nurseries until they are 18-20 inches high. They are then set out in the fields. Sisal may also be propagated from suckers which grow from the rhizomes of the plant, and occasionally from seed, however this last is not practical as sisal rarely sets seed.

Henequen may be propagated in the same manner as sisal. However, henequen does not produce bulbils as plentifully as sisal and therefore suckers are more commonly used. Seed is rare. Out of 800 henequen seed collected with difficulty on our Cuban plantation, 12 germinated and one survived.

The impetus to the growth of the agave fiber industry came from the development of a mechanical decorticator and the reaper. The first decorticator recorded was understood to have been the invention of a Mexican friar but was apparently not too successful. In 1857 a man of the name Solis, also a Mexican from Yucatan, invented a decorticator or raspador which was the forerunner of the present day decorticators. All are based on the crushing or scraping of the leaves by knives mounted on a wheel working against a curved metal plate.

With the invention of the decorticator the expansion of the henequen industry made rapid strides. The invention of the grain binder or reaper gave added impetus through the demand for binder twine. This was also, no doubt, responsible in part for the growth in East Africa and elsewhere of the sisal industry. In 1916 the price of henequen reached 23 cents U.S. per pound and the exports were almost a million bales or 200,000 long tons. This was the peak in exports for Mexico.

During the period between the first and second world wars despite fluctuations the production trend of the agave fibers was upwards, Mexico being the exception. The introduction of the corn binder had increased the demand for agricultural twines and the production of henequen and sisal spread to the other countries.

Henequen was now being raised in appreciable quantities in Cuba and Salvador although considerably behind Mexico. The planting of sisal had continued to expand in British East Africa which now led Mexico in the production of agave with Indonesia in third place, smaller amounts coming from Haiti, Portuguese and French Africa and Madagascar.

During the period from 1935 through 1938 when the second world war began the average sisal production from East Africa was 123,000 tons per year. Mexican production of henequen averaged 94,500 tons and Cuban production 13,500 tons. During the same

period Salvador averaged 3,000 tons. Indonesian sisal production averaged 90,500 tons, Haiti 6,000 tons with Mozambique producing 21,500 tons. Brazil had not yet started on the cultivation of sisal.

During the second world war and on through 1947 the Mexican fiber output was sold to the U.S. Defense Supplies Corporation. The Cuban government controlled that country's exports and Britain controlled the African sisal exports. Haitian production likewise was controlled by the U.S. government. In all these areas planting was accelerated to compensate for the loss of Manila fiber from the Philippines and sisal from Indonesia, and to take care of the increased war-time demand for cordage.

After the close of World War II the demand for binder twine decreased rapidly with the increased use of grain combines. However, the invention of the pickup hay baler using twine bale ties began to compensate for the diminishing demand for binder twine. Also the substitution of sisal for manila which took place during the war was in many cases continued because of the price differential, thus maintaining the demand for sisal fiber and to some degree henequen.

In 1946 the total sisal production amounted to 179,500 tons. The world's henequen production for the same year was 124,000 tons. By 1950 the world's production of sisal reached 306,000 tons with British East Africa alone producing 162,500 tons. The Brazilian production had reached 51,500 tons and Haiti 33,500 tons. For the same year the total world production of henequen amounted to 114,500 tons with Mexico's share being 96,500 tons, Cuba's 15,500 tons and Salvador's 2,500 tons.

Last year, 1957, the world production of sisal amounted to 495,000 tons, almost 33% over that of 1950. Of this amount British East Africa produced 226,000 tons, Brazil 115,000 tons with the balance split up among Portuguese Africa, Indonesia and Haiti. For the same year the henequen production totalled 117, 500 tons of which Mexico accounted for 106,000 tons, Cuba 10,000 tons and Salvador 1,500 tons.

So far little has been said of prices. It was mentioned that during the first world war henequen had reached 23 cents per pound. This level was held only momentarily and by 1932, the early part of the depression, henequen had dropped to less than 3 cents per pound. It eventually recovered and the average for this fiber from 1935 through 1938 was 5.1 cents per pound. During the second world war the price was controlled but averaged between 8½ cents and 9 cents. With the close of the war and the removal of restrictions plus the post-war demand for all products, the price rose and by 1947 ranged between 14 and 15 cents. By 1950 it had eased to 12½ cents but the Korean war pushed the price back up and in 1951 it reached an all time high of 27 cents landed New York. Since then the decrease has been continuous and at present henequen is nominally quoted in New York as 7¼ cents for "A" grade. It should be mentioned at this time that with the growth of a cordage industry in Mexico which was given a tremendous boost by the war time demand for cordage of all kinds, Mexico has little "A" grade fiber to export and because of competition from sisal there is little demand for the inferior grades of henequen in the world market except for upholstery.

Sisal prices have in general followed the same pattern as those of

henequen. In 1935 both African and Haitian sisal were quoted at 4.3 cents in New York. Indonesia sisal was about 4.7 cents. Portuguese and Brazilian sisals were not yet quoted. By 1938 all sisal prices had dropped about ½ cent. During the next year sisal had strengthened and was selling in the neighborhood of 8 cents. In the war years the price was fixed by the British Government and of course there was no Indonesian sisal available. By 1948 when sisal was again traded in the open market the price had advanced to 17.5 cents for African and 17 cents for Haitian. Because of the war Indonesian sisals were limited and priced at about 22.3 cents per pound. Like henequen, sisal prices rose in 1951 to 29-31 cents per pound but by 1957 had receded to 9¼ cents. Brazilian sisal which was first quoted in 1947 at 16⅜ cents went to 27 cents in 1951 and last year was quoted at 7⅞ cents.

Both Mexican henequen and Brazilian sisal are subsidized indirectly by their respective governments. This allows both countries to sell in the world market at artificially low prices, substantially depressing the market. It is doubtful if at the present time many sisal or henequen producers outside of these two countries are operating at a profit. This will eventually reduce production and, assuming the demand to remain the same or to increase, will bring the prices back to an economic level.

In British East Africa during 1957 the average cost of production of sisal fiber was £48.0.0 per ton or 6 cents U.S. per pound. Of this amount £22.0.0 or 2.75 cents went for labor. The net sales receipts were £50.0.0 per ton or 6.20 cents per pound, a margin of 20 cents which was not sufficient to take care of capital charges, such as depreciation. A recent report on the East African sisal industry estimates that the present price of sisal is a good £20.0.0 per ton or 2.5 cents per pound too low. Cost figures are not available for Brazil but we assume that due to the governmental subsidy, which is actually a currency manipulation, the sisal growers are doing all right. In Indonesia sisal is no longer considered a profitable crop and is disappearing. Haiti and the other African producers are in about the same position as British East Africa. As far as is known Mexico is having some difficulties with fiber production though not with processing. In Cuba, the other henequen producing country of any importance, the planters are either losing money or just breaking even.

The British East African sisal growers have tentative plans to meet with the Brazilian bankers and growers some time before the end of the year in an effort to stabilize the world market for sisal fiber. It is hoped that a price can be set that will be economical for both producer and consumer and not attract substitution from synthetics or other fibers. It is believed that this can be achieved without restricting production.

Since 1955 world production of sisal fiber has increased 90,000 tons while consumption has increased 84,000 tons. Furthermore the yearly carry-over has been decreasing each year and for 1958 is expected to be 24,000 tons or about 5% which is certainly not excessive. This indicates little over-production so it appears that the sisal market could be stabilized without crop restriction.

Indonesia, which before the war was the second largest producer

of sisal, has never regained its position and in 1957 produced only 32,500 tons as compared to a 1935/1938 average of 90,500 tons. The peak post-war production was 35,000 tons in 1955. Since then each year has seen a decrease and this is expected to continue because of the political and labor situation.

Sisal and henequen have some competition from synthetics and paper. The greatest use of sisal and henequen is in the agricultural twines, baler and binder, where the twine is used once and thrown away. Synthetic cordage is too expensive to compete with sisal and henequen twine in this usage. The same holds true of wrapping twine. Wrapping twines however have a competitor in such products as cellophane and gummed paper tape. Synthetic fiber is very definitely encroaching on marine uses of agave fiber. On the other hand there is a growing demand for sisal fiber for use as a strengthener in plastics. In tropical areas where pulpwood is not plentiful, sisal and henequen could be used for the manufacture of paper. Increasing amounts of sisal are also used as floor coverings.

With regard to the agricultural twines, the demand for binder twine decreases yearly although it is believed that there will probably be some demand for years to come. At the moment it appears that the demand for baler twine might be leveling off and there is no immediate threat in the way of competition. There is a threat in the future. The increased use of forage harvesters and the improvement of crop dryers could greatly reduce the need for hay balers and baler twine. In addition there is presently being developed a machine for pelletizing forage grasses in the fields, all of which tend to eliminate the need for baler twine. Substitutes for sisal baler twine have been tried, such as glass fiber and paper. No satisfactory substitute has been found. All have either been too costly or have not functioned properly.

Another potential factor working against the continued and large volume use of the agaves is the ever increasing cost of production. The world's production of hard fibers comes from the tropical areas of the earth that have been considered as underdeveloped areas. As these areas become enlightened and the standards of living improve, wages go up. Labor is one of the largest items in the cost of hard fibers and as far as is known at present will continue to be. Through the years much has been done to mechanize the harvesting of both agaves and manila but at the moment there are no prospects of mechanizing the cutting of the agave leaves or the felling of an abaca or manila fiber stalk. Such a machine is possible but would be so complicated and the cost so high that the chances are that little relief in cost would be gained. Increased costs of agave fiber could well lead to the development of a cheaper substitute. Aldous Huxley once pointed out that if coffee and tea grew in Western Europe and were picked by people drawing European wages, the cost to the consumer would be such that the ordinary consumer simply could not consume. The same might be said of henequen and sisal.

Since the fall in price of the agave fibers which followed the end of the war, the producers of these fibers have been casting about for ways to utilize the waste products resulting from the decortication of sisal and henequen in order to reduce costs. For many years there

has been a market for the short fiber or flume tow extracted from the waste or bagasse, large quantities of which are used for padding in the automotive and furniture industries. The sap or juice is a source of genins and pectins, and a high grade wax comparable with carnauba is obtained from the leaf cuticle. Likewise alcohol can be distilled from the trunks which also yield a short fiber suitable for brushes. Unfortunately to date none of these products except flume tow have been produced commercially although the British do have a pilot plant producing steroidal hecogenin, a precurson to cortisone, and Mexico has done a great deal of work on wax extraction.

It is doubtful that the prices of sisal and henequen will go much lower. It is equally doubtful that there will be any increase in production under present conditions. Production appears to be leveling off. The possibilities for lower production and increased prices are greater. With present prices many sisal and henequen planters will not maintain their fields. This will eventually reduce production which by itself, assuming consumption to remain as is, will tend to increase prices. In addition the ever continuing search for new uses for agave will tend to increase consumption. A point will be reached when it will again pay the grower to plant new fields and the cycle of feast and famine will start anew.

Central American Abaca Program of the Government of the United States

J. J. Romeo*

I. ORIGIN OF THE PROGRAM

The average person has encountered the word "abaca" only in crossword puzzles. Very few people know that it is a fiber of great importance, so compelling, in fact, that our Government has expended a net of around $18 million since Pearl Harbor to produce it on plantations established in the tropics of Central America.

The Government's abaca venture began when the Japanese occupation of the Philippines at the start of World War II choked off shipment of the fiber to the United States. At the time, our country had less than a year's supply on hand or in the pipeline. This would have been disastrous except for the foresight of our own Department of Agriculture, specifically Dr. Harry Edwards, and the interest and know-how of the United Fruit Company.

With the help of Henry Peabody and Charles Harvey, two American-born abaca plantation operators in Davao, Edwards managed, in 1925, despite many frustrations, to land 1,438 abaca seed pieces at the United Fruit Company nursery in Panama. From these pieces was made a field planting of one acre. By 1939 this one acre had been expanded to 2,000 acres of healthy abaca.

The Company ran into trouble, however, in the development of a cleaning process for its fiber. It tried the Philippine Hagotan, but found this impractical because of the relatively higher labor costs in Central America. It then turned to mass-scale mechanization and was occupied with solving this problem when World War II broke out.

The War changed the outlook and approach to abaca production in the Western Hemisphere from a commercial to defense basis. Cost considerations and profits became secondary.

With the Reconstruction Finance Corporation doing the financing and exercising over-all supervision of the project, and the Department of Agriculture providing valuable technical guidance, the United Fruit Company began, a few days after Pearl Harbor, to expand its abaca acreage, using as seed material the plantings in Panama. By 1944 there were about 28,700 acres of abaca in Panama, Costa Rica, Guatemala and Honduras.

In about two years the land had been planted, and roads, bridges, canals and railway systems had been provided in the jungle land used for the new project. Whole villages had been built for the use of the employees and, amid many frustrating difficulties, using the Krupp-Corona as a base, processing plants had been designed and set up and were turning out a fiber processed by way of a production line more highly mechanized than ever before.

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The Government and private industry had teamed up to supply, with almost unbelievable speed and efficiency, a much-needed commodity in time of crisis.

Even though, under the pressures of Pearl Harbor, speed was of much greater importance than economy in the installation of the plantations, the initial job was done at remarkably low cost. This was due not only to the efficiency and improvisation of the Company, but to the availability of existing facilities which the Government was permitted to use at relatively low cost or rental. Thus the five plantations were installed at a cost of approximately $11,000,000, or $380 per acre. Individual costs at each location were as follows:

	Acres	*Cost*	*Cost per Acre*
Costa Rica (2 plantations)	11,500	$4,500,000	$390
Guatemala	5,700	1,800,000	315
Honduras	5,000	1,700,000	340
Panama	6,500	3,000,000	460
	28,700	$11,000,000	$380

In today's market, due to price increases in materials and supplies, as well as wages and fringe benefits, cost of these installations would run between $1400-$1600 per acre.

Abaca production from the Government projects during World War II and the subsequent rehabilitation period (1942-1949) amounted to approximately 136,000,000 lbs. at a cost of approximately $29,000,000, or 21¢ per lb. The cumulative loss for the 7-year period was $3.6 million.

II. POST-WAR PERIOD

Guided by the general feeling that the Government ought to get out of business when the national emergency ended, RFC made efforts in 1946-1948 to dispose of the abaca plantations to private industry.

The idea of making some of the projects available to nationals of the countries involved, to be operated on a cooperative basis, was thoroughly explored; however, this was dropped as impractical and uneconomical.

The fact that the project had not made money and, indeed, had not quite broken even, was enough to discourage the United Fruit Company and other experienced agricultural enterprises from taking over the plantations.

Fiber was still considered of critical importance (in fact the Civilian Production Administration directed that abaca be stockpiled in 1946) and as a result it became necessary for the Government, because of the lack of interest by private industry, to continue in abaca production after the War. New legislation was required and was enacted into law on August 10, 1950 in the form of the Abaca Production Act of 1950 (Public Law 683—81st Congress).

The Bill included these major provisions:

1. The Projects would be continued until March 31, 1960, unless Congress or the President ordered earlier termination.
2. New acreage could be added, provided the total in cultivation did not exceed 50,000 acres.
3. A Revolving Fund of $35,000,000 was established to finance the program.

4. Research could be undertaken to locate the best available abaca land as well as to improve existing crop culture and processing methods.

When the Abaca Production Act of 1950 became law, there were approximately 25,000 acres of abaca in the Government's project. Less than two weeks after signing the new law, President Truman directed RFC to take immediate action to increase the acreage to the full 50,000 acres permitted by the Act. This action was taken as a result of the outbreak of the Korean War, and the anticipated shortages of fiber.

Soil Surveys

RFC thus embarked upon an expansion program and, as the first step in this direction, asked the Department of Agriculture to send teams of land experts to locate the best lands available in the Western Hemisphere for cultivation to abaca.

Groups of experts from the Department's Bureau of Plant Industry conducted the surveys. They set up headquarters in Turrialba, Costa Rica. These men suffered many privations and inconveniences in this assignment, since most of the areas investigated were practically jungles. They examined land on foot or mule-back, by air and by boat. The surveys took about a year and, in the process, over 200,000 acres of land were catalogued. Suitable lands were found, and the Department recommended areas in Nicaragua, Honduras, Costa Rica and Ecuador.

With the end of the Korean hostilities, and Philippine supplies becoming more plentiful, the President, on April 10, 1953, ordered curtailment of all expansion projects. Therefore, no new projects were added.

The value of the soil surveys was substantial in spite of the fact that the expansion program for which they were undertaken did not develop. In a sense the surveys actually made the expansion unnecessary, because they provided a ready inventory of lands which could be made to produce abaca in about a year and a half after planting.

The Long-Term Agricultural Research Program

Very little or no research was undertaken on abaca by the Government during the War. This was due primarily to two things:

1. Extreme pressure for quick production during the War.
2. Indecision as to the future of the program when the war ended.

However, by virtue of the specific provision in the law enabling research, RFC immediately established a long-term program, to be headed also by experts from the Department of Agriculture. This program was carried on for approximately seven years at a cost of about \$80,000 per year. It developed for the first time on abaca scientific data on crop culture, diseases and pests. This not only contributed to the general knowledge on the crop, but materially assisted in the reduction of the costs of operation of the Government program. Practically all problem areas in abaca production were explored by these scientists during the program, and complete reports were rendered thereon.

Mechanical Research

The Government also engaged in research aimed at improving the abaca processing equipment. The Armour Research Foundation, of the University of Illinois, Institute of Technology of Chicago, was engaged for this purpose. This work was started in early 1951 and lasted about one year. It led to many recommendations by Armour for the improvement of the decorticating equipment as well as the development of machinery for the cleaning of abaca waste. A good part of the recommendations was adopted; however, many of them were not. Although they were technically sound, the projects could not pay out within the remaining years in which the plantations would remain in operation.

As to abaca waste, Armour recommended a process (Hydrapulper) by which waste could be cleaned and landed in New York at a price of four to six cents per pound. Again, this process was not adopted in view of the competition from related materials and the lack of early pay-out. However, this project could be indulged in at any time in which a shortage of competitive materials developed or at such time as the cost of competitive materials rose beyond the related costs of producing waste in Central America.

III. POST-WAR OPERATING EXPERIENCE

Production from the Central America abaca projects under authority of the Abaca Production Act of 1950 has amounted to 192,600,000 pounds, at a cost of about $18,000,000, or 24.5¢ per pound. This cost is relatively high and has resulted in financial losses to the Government. This post-war loss has amounted to $14,700,000 which, when coupled with the $3,600,000 loss experienced during the War, amounts to a grand total of $18,300,000 which the Government is out-of-pocket under the Central American Abaca Program since its inception in 1942.

This total loss is substantial; however, it is outweighed many times by these returns therefrom to the Government:

(1) It provided fiber during World War II and Korea, which otherwise would not have been available.
(2) It provided a stabilizing influence upon the market in the immediate post-war period when supplies from the Philippines were short.
(3) It has complemented the Government stockpile program, providing a ready source of expansion to war-time requirements, thereby making unnecessary the stockpiling of the full war-time requirements. This has resulted in savings of many millions of dollars in stockpile costs—probably considerably in excess of the entire loss suffered under the Central American program since inception in 1942.

It is still felt by those in Government connected with the Central American Abaca Program that these projects could be operated at a modest profit, particularly by private industry. This is based on the

fact that the plantations have been operated in recent years more from the point of view of the health of the cultivations for use as seed in time of emergency than they have been for purposes of high immediate production and profit. Because of the fact the future of the program was almost always in doubt, there were many long-term practices which would have resulted in ultimate economy and operations that could not be undertaken under the Government program. For example, in 1950-1951 when it appeared that the program would continue for some time, the Government decided to engage in an extensive fertilizer program, aimed at increasing production. This involved expenditures of approximately $1,000,000 a year for fertilizer, which would not be recovered for from one to two years after application. This fertilizer practice resulted in tremendous production increases in 1952 and 1953, from an average of 15,000,000 lbs. per year prior to that time, to 32,000,000 lbs. in 1952 and 34,000,000 in 1953.

During these years, the program losses were $500,000 in 1952 and $200,000 in 1953, which were the lowest in the history of the program; actually, however, operations during those years would have resulted in profits except for a disastrous fire at the Honduras project. The loss sustained from the fire was over $1,000,000 but in addition, it precluded processing operations at Honduras until the factory could be rebuilt, resulting in severe stalk loss.

However, the fertilizer program was terminated when curtailment of the program began since there was no assurance further cuts in acreage would not be made as supplies of abaca became more plentiful.

The original cultivations and facilities, as previously described, were installed under the pressures of World War II and there was little time to make soil experiments and analysis. Time was the essence, therefore certain arbitrary decisions had to be made. One of the decisions made was that land from which bananas had been produced could also be used successfully in the production of abaca, since the plants are very similar. In addition, the plant variety was limited only to those which were on hand at the Fruit Company nursery.

Experience subsequently showed that soil requirements for bananas and abaca, though similar, are not the same. As to variety, experience as well as research programs has determined that the major variety used in Central America (Bungulanon) is not the best adaptable for Central America soil and climate, at least under present conditions, and that there are other varieties which could do a better job.

It is common practice in plantation-type abaca operations to engage in crop rotation periodically. For example, the Dutch in Indonesia alternate from sisal to abaca and vice versa every 7 years. Varieties are changed to meet latest developments and possibly changes in climate or soils. This is sound practice which will pay dividends; however, because of the limited life of the program, as well as authority, the Government never was in a position to engage in these practices.

We who operate this program feel that if normal commercial practices and the research data now on hand could be applied to this activity, per acre production could be materially increased and costs

reduced to a level of from 16 cents to 20 cents per pound. In today's market, with top abaca grades selling for 26 cents per pound, a modest profit could be realized. So, to someone interested in moderate profit in an established industry, and we say this in spite of the threat of synthetic fiber, we feel the Central American abaca projects offer an attractive proposition, particularly in the light of the marked decrease in Philippine production in recent years. The seriousness of this decrease can best be understood when it is realized that production from the Philippines in pre-war periods amounted to almost 400,000,000 pounds per year. Production in 1958 is now running at the rate of 190,000,000 per year, a decrease of over 50%. Of course, a substantial capital investment would be required, but return of investment would begin immediately, since a going concern would be assumed.

After extensive study of the supply situation and in consideration of the reduction of emergency requirements from five to three-year basis, the OCDM decided on July 21, 1958 that the Central American Abaca Program should not be continued beyond the expiration date set in the Act, March 31, 1960.

The OCDM has directed that an attempt be first made to dispose of the plantations as a going concern, so that the source of supply will remain in this hemisphere. Failing this, the Government will proceed to butcher-harvest the cultivations, and thereafter cannibalize the facilities. The butcher-harvest process will require from one year to eighteen months from date of commencement. It is estimated that from 15,000,000 to 20,000,000 pounds of fiber would be recovered in a butcher-harvest. Costs under butcher-harvest are much lower than on a normal operating basis, since there are little or no maintenance expenses. Only expenses associated with processing and harvesting of the fiber are incurred. Thus the standing crop has a potential net value to the Government of between one and one-half million dollars. Sale of the remaining assets, such as the decorticating equipment, transportation equipment, housing, etc. will be made on a salvage basis after completion of butcher-harvest.

It is probable that elimination of the Central American production from the market will have some impact upon the abaca market. This would seem a natural result, since it will tend to further restrict abaca supplies beyond the rate being experienced today. However, this is a consequence over which the Government had no control. The purpose of the Central American abaca program is strictly one of defense and with the elimination of the defense necessity, there remained no further justification for continuance of the program.

Because of its limited acreage (3500), no attempt will be made to interest any concern in the purchase of the Guatemala plantation. Butcher-harvest of this facility has already begun.

Attempts have been made to interest private concerns in the Costa Rica plantation. To date these efforts have been unsuccessful. Inasmuch as it will require from one year to 15 months to complete the butcher-harvest on an orderly basis, the liquidation must commence by no later than January 1, 1959, if it is to be concluded by the termination date of the Law, March 31, 1960. Therefore, we have set December 31, 1958, as our deadline in connection with our efforts to sell on a "going-concern" basis.

Hard Fiber Investigations in Florida[1]

J. F. Joyner and C. C. Seale[2]

Fiber obtained from the leaves of sisal (*Agave sisalana* Perrine), henequen (*A. fourcroydes* Lemaire), and furcraea (*Furcraea gigantea* Vent. and *F. cabuya* Trel.) is known as hard fiber (4). This type of fiber is generally used in the manufacture of binder and baler twines, cordage and bags (3,4,5,6,7,9). The importance of hard fibers in national economy can best be measured by the amount and value of the imports. In 1957 a total of 124,910 long tons of sisal and henequen values at about 18 million dollars was imported into the United States (1).

The sisal plant is cultivated for fiber production mainly in British East Africa, Mozambique and Angola, Haiti and Brazil. But in Mexico, where it is indigenous, it is grown only to a limited extent for domestic use. Dr. Henry Perrine introduced sisal into Florida from the Yucatan Peninsula, Mexico. The plant became readily acclimatized in the southern part of the state, but it has never been grown on a commercial scale for fiber production. However, for many years nurserymen have collected and exported bulbils from wild stands of sisal plants in Florida and these plants have played an important part in the establishment of plantings of sisal in other areas (7). Sisal is propagated mainly from bulbils formed on the "pole" or flowering stalk of the plant, and to a lesser extent from "suckers" which develop around the plant. The life of sisal is somewhat shorter than that of henequen; poling generally takes place in 3 to 11 years and is affected by soil and climatic conditions (4,9). Sisal is generally distinguished by its dark green leaves which are usually free of marginal prickles (7).

The henequen plant is indigenous to Mexico and is grown extensively for fiber production in the Yucatan Peninsula. It is also grown on a small scale in Cuba. Outside of these areas, however, little or no henequen fiber is produced for export (4,5,7,9). The life of the henequen plant is 10 to 20 years or more, and like sisal it flowers once and then dies. Henequen is generally distinguished by its thick grey leaves with hooked prickles along the margins (3). In general, henequen is propagated by sucker plants. However, when plants have to be transported over long distances for the establishment of a plantation, it is more convenient to use bulbils. Seed is only used for crop improvement through breeding and selection (4).

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[1]The research work on which this paper is based was conducted cooperatively by the Crops Research Division and the Agricultural Engineering Research Division, A.R.S., United States Department of Agriculture and the University of Florida Agricultural Experiment Station.

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The furcraeas are not grown as extensively as sisal or henequen for fiber, and most of the species of this plant are indigenous to the Western Hemisphere (4). *F. gigantea* is grown for fiber in Mauritius, Brazil, Madagascar and Venezuela, while *F. cabuya* is cultivated in Costa Rica and Panama (4,9). Robinson believes that *F. cabuya* may be synonymous with *F. gigantea* (7). The fiber is somewhat similar in appearance to that of sisal, but is weaker in quality. Furcraea is propagated by bulbils and by sucker plants. The latter method, however, is preferred because, it is claimed, suckers produce plants that have a longer life span (4,9).

EXPERIMENTAL PROCEDURE

A hard fiber variety experiment was set out on Immokalee fine sand near Lake Worth, Florida in 1952. Five varieties were included in the test: two varieties of sisal (one collected locally and the other introduced from Haiti); one variety of henequen introduced from Mexico; two species of furcraea (one obtained locally and the other from Costa Rica).

The design of the experiment was a randomized block with 4 replications. Plots, 216 square feet in area, were planted with 3 sucker plants of each variety in February 1952. In the spring of 1952 and 1953, fertilizer was applied at the rate of 1000 pounds of a 12-4-8 mixture per acre. In 1954, 1955 and 1956 the same amount of fertilizer was applied in split applications, half in the spring and half in the fall.

The first harvest from this experiment was made in October 1955, about 44 months after planting, and the second harvest was made in September 1956. Leaves making an angle of 60 degrees or less with the horizontal were cut by hand, and the green weight was taken. From these weights, the green yield per acre was calculated.

A representative sample of leaves from each plot was weighed and decorticated. The fiber obtained from these samples was washed, oven dried at 200° F, conditioned for 48 hours at 70° F. and 65% relative humidity before being weighed. The percent fiber on a green weight basis and the fiber yields per acre were calculated from these dry fiber weights.

The quality of the fiber from each plot was measured for tensile strength, shear, wear and flex in the laboratory at the Everglades Experiment Station by the basic methods described by Schiefer (8) and Berkley, *et al* (2).

RESULTS

Growth and Yield

Data for mean leaf length, green yield, percent fiber and fiber yield of the varieties in a hard fiber experiment on Immokalee fine sand in 1955 and 1956 are given in Table 1.

F. cabuya from Costa Rica had the longest leaves, while *F. gigantea* had the shortest leaves. Varietal differences in leaf length were highly significant in 1955, but were not significant in 1956.

TABLE 1.—Leaf Length, Green Yield, Percent Fiber and Fiber Yields of Hard Fiber Varieties.

Variety	1955	1956	Mean
	Leaf length, inches		
A. sisilana, P. I. 236425, Haiti	43	47	45
A. sisilana, Florida	39	43	41
A. fourcroydes, P. I. 182788, Mexico	44	46	45
F. gigantea, Florida	41	39	40
F. cabuya, P. I. 182789, Costa Rica	54	49	52
LSD 5%	7	N.S.	
LSD 1%	10	N.S.	
	Green yield, thousands pounds per acre		
A. sisilana, P. I. 236425, Haiti	37.8	35.9	36.9
A. sisilana, Florida	30.7	30.5	30.6
A. fourcroydes, P. I. 182788, Mexico	44.1	39.4	41.8
F. gigantea, Florida	20.9	21.1	21.0
F. cabuya, P. I. 182789, Costa Rica	26.1	29.8	28.0
LSD 5%	14.2	11.0	
LSD 1%	N.S.	N.S.	
	Percent fiber of green yield		
A. sisilana, P. I. 236425, Haiti	3.00	3.59	3.30
A. sisilana, Florida	3.01	3.40	3.21
A. fourcroydes, P. I. 182788, Mexico	3.18	4.33	3.76
F. gigantea, Florida	2.57	3.25	2.91
F. cabuya, P. I. 182789, Costa Rica	1.85	2.41	2.13
LSD 5%	.44	.15	
LSD 1%	.61	.21	
	Fiber yield, pounds per acre		
A. sisilana, P. I. 236425, Haiti	1,134	1,289	1,212
A. sisilana, Florida	924	1,037	981
A. fourcroydes, P. I. 182788, Mexico	1,402	1,706	1,554
F. gigantea, Florida	537	686	612
F. cabuya, P. I. 182789, Costa Rica	483	718	601
LSD 5%	386	373	
LSD 1%	541	523	

Green yields fell into three general categories; henequen ranked first, the sisal varieties came next, while the furcraeas produced the lowest yields per acre. Differences between varieties in green yield were significant in both years.

Henequen had the highest percent fiber. The sisal varieties were somewhat lower in percent fiber, but did not differ significantly from each other. Both species of furcraea were substantially lower in fiber content. Varietal differences in percent fiber were highly significant in both years.

TABLE 2.—TENSILE STRENGTH, SHEAR, WEAR AND FLEX OF HARD FIBER VARIETIES.

Variety	1955	1956	Mean
Tensile strength, thousands pounds per sq. inch			
A. sisilana, P. I. 236425, Haiti	47.9	60.5	54.2
A. sisilana, Florida	46.8	55.5	51.2
A. fourcroydes, P. I. 182788, Mexico	34.9	40.5	37.7
F. gigantea, Florida	37.1	41.1	39.1
F. cabuya, P. I. 182789, Costa Rica	32.6	32.5	32.6
LSD 5%	3.7	3.9	
LSD 1%	5.2	5.5	
Shear, thousands pounds per sq. inch			
A. sisilana, P. I. 236425, Haiti	17.2	19.3	18.3
A. sisilana, Florida	16.8	19.2	18.0
A. fourcroydes, P. I. 182788, Mexico	15.3	16.5	15.9
F. gigantea, Florida	13.1	15.7	14.4
F. cabuya, P. I. 182789, Costa Rica	12.4	15.3	13.9
LSD 5%	1.5	1.9	
LSD 1%	2.1	2.6	
Wear, cycles to failure			
A. sisilana, P. I. 236425, Haiti	892	1,330	1,111
A. sisilana, Florida	1,114	2,050	1,582
A. fourcroydes, P. I. 182788, Mexico	1,642	2,464	2,053
F. gigantea, Florida	935	1,740	1,338
F. cabuya, P. I. 182789, Costa Rica	1,307	2,328	1,818
LSD 5%	431	N.S.	
LSD 1%	N.S.	N.S.	
Flex, cycles to failure			
A. sisilana, P. I. 236425, Haiti	1,124	2,750	1,937
A. sisilana, Florida	1,406	3,221	2,314
A. fourcroydes, P. I. 182788, Mexico	2,918	8,520	5,719
F. gigantea, Florida	811	4,323	2,567
F. cabuya, P. I. 182789, Costa Rica	1,523	7,787	4,655
LSD 5%	833	3,312	
LSD 1%	1,169	4,643	

Henequen produced the highest yield of fiber, an average of 1554 pounds per acre for the two years. The sisal varieties varied in yield from 1212 to 981 pounds per acre, with the Haitian sisal outyielding the local variety. The furcraeas gave very poor yields of fiber, which were practically the same, about 600 pounds of fiber per acre. Differences between varieties in fiber yield were highly significant in 1955 and 1956.

QUALITY

Fiber quality measurements of tensile strength, shear, wear and flex of the varieties in a hard fiber variety experiment on Immokalee fine sand in 1955 and 1956 are given in Table 2.

Differences between varieties were highly significant for tensile strength, shear and flex in both years; they were significant for wear in 1955, but were not significant in 1956.

The tensile strength results fall into two general categories. The varieties of sisal had similar but higher strength values, while henequen and the furcraeas had lower but related values.

Sisal had the highest shear values, which differed very little for the two varieties; henequen ranked next, and the furcraeas had the lowest shear values.

On an average, henequen had the highest and sisal the lowest wear and flex values, with the furcraeas taking an intermediate position.

LITERATURE CITED

1. Anonymous. U. S. 1957 imports of vegetable fiber (except cotton) given in value. Foreign Agric. Cir. FVF3-58, U. S. Dept. Agric. Sept. 1958.
2. Berkley, E. E., Hessler, L. E., Burneston, E. B. and Chew, C. F. A study on the quality of abaca fiber. U. S. Dept. Agric. Tech. Bull. 999. Oct. 1949.
3. Dewey, L. H. Sisal and henequen, plants yielding fiber for binder twine. U. S. Dept. Agric. Cir. 186. Oct. 1931.
4. Dewey, L. H. Fiber production in the Western Hemisphere. U. S. Dept. of Agric. Mis. Pub. 518. 1943.
5. Edwards, H. T. Production of henequen fiber in Yucatan and Campeche. U. S. Dept. Agric. Bull. 1278. Oct. 1924.
6. Robinson, B. B. Outlook for the production of long vegetable fibers in south Florida. Proc. Soil Sci. Soc. of Florida 8: 119-126. 1946.
7. Robinson, B. B. Unpublished data. Cotton and Other Fiber Crops Section, U. S. Dept. of Agric. March 1951.
8. Schiefer, H. F. Machines and methods for testing cordage fibers. U. S. Nat. Bur. Standards Jour. Res. 33: 315-339. 1944.
9. Seale, C. C., Joyner, J. F. and Pate, J. B. Agronomic Studies of fiber plants—Jute, sisal, henequen, furcraea, hemp and other miscellaneous types. Univ. of Fla. Agric. Expt. Sta. Bull. 590. Sept. 1957.

Sansevieria Production in Yucatan, Mexico

Renan Manzanilla*

It should first be clearly understood that I am not the person previously invited to speak on this program about sansevieria and that I, myself, have not had personal experience in the cultivation of this plant. Instead, I am working in the industrial phase of the enterprise, not as manufacturer but as Technical Representative in the Mexico Zone of a large textile machinery manufacturer in Ireland. Consequently all the information that I shall try to pass on to you has been gathered from chats with people who actually are planting and from what I have observed when visiting their plantations.

I trust, therefore, that you will excuse me if, after having heard what I have to say, you find lack of accuracy or failure to mention subjects of interest. In other words, do not blame me but the other person for not having come.

To my knowledge, these friends who have pioneered the cultivation of sansevieria in the State of Yucatan, Mexico, started doing experimental work with the plant some 25 years ago. It seems that they tried different varieties and finally came to the conclusion that the spotted type, commonly known as Guineensis, was the most adaptable to the characteristics of the soil in Yucatan.

At this point I would like to mention that the soil in that section of Yucatan is little more than limestone with a little humus on top of it, where there is anything at all on top. I have made this point rather emphatic since, for the most part, there is nothing else but the bare stone. Nevertheless, the planting laborer manages to set the suckers some 12" apart in the row when planting a new field.

It seems that, at first, they tried to make the planting by means of leaf sections, but the reproduction was rather slow and scattered, perhaps because of the nature of the soil. With suckers, they can always manage to put them in the place wanted, even if by side-wedging with small stones, so that they will stay in place and ultimately produce a good root system.

In regard to maturity, the general idea seems to be that it will take at least 4 years before reaching such stand and growth that the first leaves can be harvested for fiber extraction. It is also said that when using leaf cuttings or sections for planting, the growth before maturity will take over 6 years, and it is never satisfactory.

My friends, the Sanseviera "Apostles," claim that this plant has the great advantage of not needing any weeding at all, after the first year, because it is an absorbing and dominating plant, overgrowing any others near by. Up to the present time the planters are not using any fertilizer. Although some have tried it they have given it up on account of its high cost. Anyway, that seems to be their general experience.

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Planters in Yucatan use natural shade for the variety of sansevieria which they grow. By this I mean that they do not plant shade trees for this purpose but simply plant the sansevieria under trees already growing. They claim that the falling leaves from these trees act as an automatic fertilizer; and that with shade humidity is better preserved.

There is not much cultivation given this crop except for the first year; and this is confined largely to the small amount of weeding that I have already referred to. Of course, weeds are not very much inclined to grow under the shade and at the same time compete with such a vigorous plant as sansevieria.

The harvesting starts after about 4 years of growth and is done by hand-pulling bundles of leaves varying in length from 25″ to 50″. The harvest usually starts about one month after the rainy season has begun. The rains generally start in May and the harvesting will continue as long as it keeps on raining, and even afterwards, because the rains will have impregnated the soil, helped the growth of leaves and left them moist and soft for some time after. It generally stops raining in December and the harvesting will last till January, not exactly because there would not be suitable leaves to be harvested, but because the natives will stop working for the planter and go to prepare their own fields for maise, one of their principal food crops. Of course I am speaking now of one large plantation, because on the small ones they stop the harvest only when there are not more mature leaves to pull. These small plantations that I have referred to are small in regard to sansevieria only, because they have sisal too.

As to the periodicity of harvesting, it has been found that to have a paying yield the same field should not be harvested again before two years. Speaking of the span of life of the stand, I am afraid that I must say that this is not yet fully established although those planted 25 years ago are still living thus definitely establishing the perennial character of this crop.

The large area devoted to sanseviera only, used to be an abandoned sisal plantation and had some of the early facilities remaining, at least the ruins of them, including the beds for Decauville rails. Thus the leaves are transportated to the decorticator by means of small, flat, uncovered wagons pulled by tractor. The decorticator used is simply an adapted version of the ordinary sisal decorticator. In those plantations where there is sisal too, and the sansevieria is more or less incidental, no adaptation at all has been made. The same decorticators are used for both types of leaves.

No washing is given the fiber after decorticating although water is applied to the leaves at the time of scraping by means of fixed piping, as in the case of sisal. When the fiber comes out of the decorticator it is taken to the drying racks also by means of rail wagons and allowed to remain there until dry. It may stay there the rest of the day and the night because the scraping job will generally end at midday or shortly thereafter. The night dew is said to act as bleacher. The collection from the drying racks will start next day if it is left over night but not until the sun is high so as to be sure that the fiber is completely dry.

The fiber is then brought to the storage and baling room and

baled in the form of layers just as in the case of sisal, using a sisal press of local manufacture. The big planter that I am speaking of also has a brushing machine but has given up brushing because the buyers would not pay a suitable differential price. There is no real grading of the fiber except for a selection before tying the bundles of leaves at the fields and for traps in the feed table of the decorticator. Some flume is also recovered but a profitable market has not been found for it. However, it easily could be cleaned by means of carding and a very good tow recovered that could be conveniently spun.

Part of the line fiber is exported to the United States and part of it sold to a mill near Mexico City. I am not aware of what the U. S. manufacturer uses it for but I suspect that it is spun in line form over a Java Cantala System built by James Mackie & Sons, Ltd. and in this form used for the center of steel cables. The plantations are not too far from the post of shipment: the farthest one being some 60 or 70 miles distant.

As for the Mexican Mill, I can say that this lovely line fiber is stapled and then processed over old type jute equipment, being spun down to 12 and 10 lbs. per spangle and used for sewing palm fiber (Ixtle de Palma) bags and also woven to make special sacks. This latter I consider not only an extravagance but also a lack of respect for such a nice fiber worthy of a lot more valuable uses.

The price of sansevieria fiber f.o.b. Port of Export is in the neighborhood of U. S. $0.15 per lb. At present the total production is about 250 long tons per year. However, it is expected that in 2 or 3 years this production will be doubled and that it will keep on growing. The yield of line fiber is about 2% of the weight of the green leaves. The production per mature acre is something like one long ton per crop or per cutting.

I know of five growers at present, two of them devoted to sansevieria only. The others are sisal planters who have sansevieria as a side business. A third one, devoted to sansevieria, will start scraping next season. The big plantation that has been referred to, if it can be called big, has a total of 800 acres and all the other planters put together will have about the same area devoted to this crop.

I took a bale of sansevieria to Belfast some years ago and it was spun in line form over a Java Cantala System near Dublin of the type referred to above. It was spun down to 12 lbs. per spangle and the report noted that it could have been spun down to 8 lbs. without difficulty. It also was reported that it went through the machine better than Java Cantala itself. The unit breaking strength of this fiber was 80 lbs. which is near to that of dry spun hemp. The knot breaking point was low as compared with hemp. In other words, it presented the same handicap as other hard fibers in regard to breaking strength at the knot.

Should sansevieria be processed over machinery especially designed for the purpose, perhaps it could be spun finer than 8 lbs. but I do not think that my Directors would be inclined to consider such designing, unless the present production could be increased to a desired extent.

I hope that I have not been too tiring and can only add my thanks to you for having listened.

Improvement of Sansevieria as A Fiber Crop Through Interspecific Hybridization[1]

F. D. Wilson and J. B. Pate[2]

Sansevieria trifasciata Prain, the common "snake plant," or "mother-in-law's tongue," has been shown to be superior as a fiber plant to other species investigated in southern Florida (Gangstad *et al.*, 1951; Joyner *et al.*, 1951). *S. trifasciata* has certain undesirable characteristics, however; clonal and seedling selection have been effective only to a limited degree in improving these characteristics. Accordingly, a program of interspecific hybridization was initiated in 1951 in an attempt to incorporate desirable characteristics of two (or, in some instances, three) species of *Sansevieria* in a single hybrid (Pate *et al.*, 1951). Since sansevierias are easily propagated vegetatively, any hybrid combination once achieved can be successfully carried on by asexual means.

Many interspecific combinations were attempted (Pate, *et al.*, 1954). In most cases, expected barriers to crossing precluded the production of hybrids. However, certain combinations were successful, and one of these, *S. trifasciata* x *S. deserti* N. E. Br., has shown much promise as a potential fiber crop. It is interesting that fertility of the F_1 plants is high; F_2 and backcross populations have been produced.

Several characteristics of the two parental species, *S. trifasciata* and *S. deserti,* are presented in Table 1. Since mechanical harvesting would be necessary for sansevieria production in Florida (Joyner *et al.*, 1951), it appears that *S. deserti* is superior to *S. trifasciata* in only two respects, its tolerance to full sunlight and its cold resistance, but inferior to *S. trifasciata* in other characteristics. Thus, it would appear that the most desirable type of fiber plant for southern Florida would be a *S. trifasciata*-like plant with the cold resistance and tolerance to sunlight of *S. deserti.*[3]

However, two important characteristics not previously mentioned regarding *S. trifasciata* are as follows: (1) the length of time required to produce a fiber crop; (2) percent fiber (Table 2). Theoretically, improvements in each of these characteristics could result from the

[1]The research work on which this report is based was conducted cooperatively by the Crops Research Division and the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture and the University of Florida Agricultural Experiment Station, Everglades Experiment Station.

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[3]This statement must be qualified somewhat. The *S. trifasciata* x *S. deserti* F_1 hybrid possesses a semi-cylindrical, rough leaf which must be crushed prior to decortication. However, after this preliminary crushing, the semi-cylindrical leaf is more easily decorticated than the flat leaf.

TABLE 1.—CERTAIN CHARACTERISTICS IN *Sansevieria trifasciata* and *S. deserti* IMPORTANT FOR FIBER-CROP PRODUCTION IN SOUTHERN FLORIDA.

S. trifasciata	*S. deserti*
1. easily propagated from leaf cuttings	1. not easily propagated
2. preference for shade	2. preference for sun
3. upright growth habit	3. ascending growth habit
4. leaves whorled	4. leaves two-ranked
5. leaves flat, petiolate, smooth	5. leaves practically cylindrical, rough
6. dense rhizome former; high density of stand	6. sparse rhizome former; low density of stand
7. yields of unharvested material increase markedly from year to year	7. yields increase very slowly
8. regrowth after harvest excellent	8. regrowth after harvest poor
9. tolerant to poor drainage	9. less tolerant to poor drainage
10. susceptible to cold	10. cold resistant
11. not susceptible to "wind burn" injury	11. susceptible to "wind burn" injury

S. trifasciata x *S. deserti* cross. For example, hybrid vigor would not be unexpected in such a wide cross. The thesis that improvement in percent fiber could be made rests partly on the assumption of polygenic inheritance. *S. trifasciata* is highly hetrozygous, a fact which has been emphasized by the wide range of variability in seedlings from a single clone. Thus, it seems probable that hybrids could be selected with accumulations of desirable genes and consequently higher fiber percentages. Preliminary evidence indicates that this is the case (Table 2, backcross hybrids particularly).

F_1 HYBRIDS

Thirty eight plants of the F_1 *S. trifasciata* x *S. deserti* cross have been produced, twenty nine diploid and nine triploid clones ($2n = 40$, and $2n = 60\pm$, respectively), (Margaret Menzel, unpublished data). The best of these are superior to *S. trifasciata* in certain respects: in fact, they are so superior that *S. trifasciata* is no longer considered the best type for fiber production.

Hybrid vigor has been considerable, especially in certain clones of the F_1 hybrids. Polyploid as well as hybrid vigor is evident in the triploid clones. This vigor is manifested in several ways, as follows:

TABLE 2.—LOW, MEAN AND HIGH PERCENT FIBER (GREEN WEIGHT BASIS) OF *S. trifasciata, S. deserti, S. trifasciata* x *deserti* F_1 DIPLOID HYBRIDS, AND (*S. trifasciata* x *deserti*) x *trifasciata* BACKCROSSES.

Species or hybrid	Number of clones tested	Percent fiber Low	Mean	High
S. trifasciata	91	.50	1.01	1.71
S. deserti	1	1.03	1.13	1.23
S. trifasciata x *deserti* F_1	29	1.01	1.34	1.89
(*S. trifasciata* x *deserti*) x *S. trifasciata*	107	.83	1.66	2.67

(1) Faster propagation and growth; (2) longer fiber leaves in comparable age material (at least up to 4 years in plants started from seed); (3) very much higher yields at first harvest. Data from yield trials involving the parental species and six F_1 diploid clones are presented elsewhere (Pate *et al.*, 1959). It may be sufficient to mention here that fiber yields from leaves more than 20 inches in length of the best hybrid exceeded *S. trifasciata* by a ratio of more than 5 : 1 on Everglades peat near Belle Glade, Florida (18 months after planting) and by a ratio of more than 7 : 1 on Immokalee fine sand near Lake Worth, Florida (28 months after planting).

Fiber percentages vary somewhat in the F_1 hybrids and the best clones are apparently superior in this respect to the *S. trifasciata* clone used as a parent (Table 2).

The F_1 hybrids exhibit almost as good cold resistance as *S. deserti* and are as tolerant to full sunlight as that species. The hybrids are equl to, or superior to, *S. trifasciata* in ease of propagation. The major disadvantages of the F_1 hybrids are as follows: (1) regrowth inferior to *S. trifasciata* (table 3); (2) leaves two-ranked and borne on a short semi-stem; (3) less tolerance than *S.* sp. to poor drainage.

Of the three disadvantages mentioned, perhaps regrowth is the most limiting. If sansevieria is to be treated as a perennial crop, this

TABLE 3.—REGROWTH OF *Sansevieria trifasciata, S. deserti* AND 6 CLONES OF *S. trifasciata* x *S. deserti diploid* F_1 HYBRIDS 6 OR 12 MONTHS AFTER HARVEST ON TWO KINDS OF SOIL. (FIGURES REPRESENT MEAN NUMBER OF PLANTS IN 8 SQUARE FEET OF EACH PLOT IN REPLICATED EXPERIMENTS. PLOTS HARVESTED OCTOBER-NOVEMBER, 1957).[4]

Kind of soil and species or hybrid	Number of plants in indicated period after harvest	
	6 months	12 months
Immokalee fine sand:		
S. trifasciata	56.3	70.3
S. deserti	4.0	9.8
S. trifasciata x *deserti* F_1:		
H51-10	38.3	45.3
-11	18.3	27.8
-12	24.7	35.8
-13	28.7	39.8
-14	21.7	27.8
-15	25.0	37.8
Everglades peat:		
S. trifasciata	------	57.0
S. deserti	------	.8
S. trifasciata x *deserti* F_1:		
H51-10	------	6.0
-11	------	13.2
-12	------	7.2
-13	------	27.6
-14	------	19.2
-15	------	21.8

[4]Severe cold damage sustained by plants in winter of 1957-58.

characteristic is critical. Reference to table 3 will show that the hybrids are intermediate in this respect between the parental species. This is basically due to the fact that the rhizome systems of the hybrids are less dense than that of *S. trifasciata*, but more dense than that of *S. deserti*. Data in table 3 also indicate that regrowth on the sandy soil was superior to that on peat. This may be due to the colder temperatures inland, where the peat soil occurs. However, the colder conditions on the peat had a more profound effect on the hybrids than on *S. trifasciata*. This at first seems paradoxical, since the hybrids are superior to *S. trifasciata* in cold resistance. There are two possible explanations for this phenomenon, as follows: (1) *S. trifasciata* has better regenerative ability after repeated killing back by frost and low temperatures. The winter of 1957-58 was unusually severe in southern Florida. New plants would begin to grow and be repeatedly killed back to the ground at the Everglades location. Vigor of the hybrids may be a disadvantage in this situation, because it leads to more rapid and succulent growth than in S. trifasciata. (2) Hybrids may be more susceptible to disease-producing organisms entering through frost-injured areas. Some disease apparently occurred in this manner in the winter of 1957-58, but it is not known whether the hybrids were affected more than *S. trifasciata*.

The triploid hybrids are considerably more vigorous than the diploids. Production of a fiber crop in one season on the peat may thus be made possible. Also, it is not inconceivable that both the diploid and the triploid hybrids may be treated as single harvest crops, making regrowth characteristics and cold susceptibility unimportant.

Fortunately, the high fertility of the diploid F_1 hybrids has allowed the production of F_2 and backcross populations. The possibilities of breeding and selection of more desirable types are thus greatly enhanced.

F_2 HYBRIDS

Segregation for vigor, growth habit and resistance to cold and disease (table 4) is considerable in the 108 clones of *S. trifasciata* x *S. deserti* F_2 hybrids grown. Presumably, segregation for other characters of importance is also occurring. However, as would be expected, the remarkable vigor exhibited by F_1 plants is apparently not present in the F_2 clones. On the other hand, the possibility cannot be discounted that hybrid vigor may occur in progenies resulting from crosses between selected F_2 clones.

BACKCROSS HYBRIDS

About 20 of the 108 clones of the (*S. trifacsiata* x *S. deserti*) x *S. trifasciata* hybrids show much promise as fiber plants. Backcross clones equal to the F_1 hybrids in ease of propagation and cold resistance (table 4) and superior to the F_1 hybrids in growth habit and percent fiber (table 2) have been selected. The period required to produce a fiber crop and regrowth characteristics are essentially unknown quantities at present. Observations indicate that vigor of certain backcross clones is equal to that of the best F_1 hybrids. Thus, it seems likely that a fiber crop can be produced in a comparable period.

TABLE 4.—DISTRIBUTION OF COLD-INJURY RATINGS (MARCH 10, 1958) IN *S. trifasciata*, *S. deserti*, *S. trifasciata* x *S. deserti* F_1 HYBRIDS, *S .trifasciata* x *S. deserti* F_2 HYBRIDS, AND (*S. trifasciata* x *S. deserti*) x *S. trifasciata* BACKCROSS HYBRIDS. IMMOKALEE FINE SANDY SOIL, NEAR LAKE WORTH, FLORIDA.

Species or hybrid	Plants in indicated rating class (number)[5] 0	1	2	3	4	5	Mean rating
S. trifasciata (clone tri C-7)	0	0	0	0	7	0	4.0
S. deserti (clone des C-1)	1	4	0	0	0	0	.80
S. trifasciata x *S. deserti* F_1	0	8	10	0	0	0	1.55
S. trifasciata x *S. deserti* F_2	1	29	44	24	10	0	2.14
(*S. trifasciata* x *S. deserti*) x *S. trifasciata*	0	10	27	52	16	3	2.77

[5]No visible cold injury to severe cold injury, 0 to 5.

It also seems probable that regrowth of some backcross clones will be superior to that of the F_1 hybrids.

CONCLUSION

The success of the *S. trifasciata* x *S. deserti* combination suggests many possibilities for future improvement of sansevieria as a fiber crop. First, it is conceivable that several other interspecific combinations would be successful and yield hybrids superior to those already produced. Since only about one-third of the described species (Brown, 1915; Greenway, 1941) are included in the collection of the U. S. Department of Agriculture in southern Florida, the potentialities for new interspecific combinations are considerable.

Secondly, the fertility of the various *S. trifasciata* x *S. deserti* hybrids suggests further breeding methods to improve sansevieria. Because of this fertility, it becomes relatively easy to make crosses between various clones with the objectives of combining desirable characteristics and utilizing hybrid vigor.

LITERATURE CITED

Brown, N. E. 1915. *Sansevieria*—a monograph of all known species. Royal Bot. Gard. Kew Bull. of Misc. Inf. 5:185.

Gangstad, E. O., J. F. Joyner and C. C. Seale. 1951. Agronomic characteristics of *Sansevieria* species. Trop. Agric. 28:204.

Greenway, P. J. 1941. Bowstring hemp or sansevieria fiber. East African Agric. Jour. 96.

Joyner, J. F., J. B. Pate, E. O. Gangstad, and C. C. Seale. 1951. The potentialities of sansevieria for fiber production in South Florida. Proc. Soil Sci. Soc. of Fla. 11:138-139.

Pate, J. B., J. F. Joyner, E. O. Gangstad and C. C. Seale. 1951. The breeding of improved varieties of kenaf, sansevieria and ramie for South Florida. Proc. Soil Sci. Soc. of Fla. 11:140-141.

Pate, J. B., J. F. Joyner and E. O. Gangstad. 1954. Interspecific and intervarietal hybridization in sansevieria. Jour. Hered. 45:69-73.

Pate, J. B., J. F. Joyner and C. C. Seale. 1959. Hybrid vigor from an interspecific cross of sansevieria. Unpublished Ms.

Sansevieria, A Potential Fiber Crop[1]

D. W. Fishler and J. B. Pate[2]

The active interest in sansevieria as a potential substitute for the cordage fibers now imported is understandable. In 1957 United States manufacturers imported approximately 170,000 long tons of hard fibers, valued at $36,000,000. Sisal accounted for 65 percent of the tonnage and 52 percent of the value, while abaca accounted for only 25 percent of the tonnage and 48 percent of the value (2). All hard fiber used in the United States is produced in foreign countries. Brazil accounted for nearly one-half and Haiti for a little over one-fourth the sisal imports into the United States in 1957. It is of interest that 93 percent of the abaca imported into the United States in 1957 came from the Philippines. Considering the great distances involved between the United States and hard-fiber-producing countries, it is understandable why fibers, particularly abaca, became strategic materials during times of international conflict (9). During World War II, when the Philippine Islands was captured by the Japanese, the allied powers lost access to unlimited amounts of abaca, their chief source of marine cordage. Governmental agencies, therefore, took steps to alleviate the situation. Considerable sums of money were spent to encourage the production of abaca in Central America and hemp in the midwestern part of the United States (4).

Manufacturers of marine cordage were forced to substitute other fibers for abaca. The fibers used were sisal, jute, henequen and American hemp (9). During the early part of World War II, the War Production Board, in cooperation with the Seaboard Railroad, harvested and processed a quantity of wild sansevieria, growing along the Florida East Coast, and converted it into ¾-inch rope. The fiber compared favorably with abaca and was better than sisal (1). These findings were later confirmed when sansevieria fiber, grown and processed in Florida, was found by the Bureau of Ships of the Navy Department to be a satisfactory substitute for abaca (4). With this encouraging development, the United States Department of Agriculture and the University of Florida Agricultural Experiment Station began a cooperative research project in 1943 to study the production and processing of sansevieria to meet the critical shortage of marine cordage fibers.

The value of sansevieria for high-grade cordage has been recognized since early times. In Africa, natives used the fiber for coarse

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[1]Research work on which this report is based was conducted cooperatively by the Crops Research Division and Agricultural Engineering Division, Agricultural Research Service, U. S. Department of Agriculture and the Everglades Experiment Station of the University of Florida Agricultural Experiment Station, Belle Glade, Florida.

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fabrics and found it very useful for fish nets used in salt water. (7). In India the fiber was used for bowstrings, which accounts for one of its common names—bowstring hemp (7). Unsuccessful attempts were made in Africa during the early 1900's to harvest wild stands of the *Sansevieria ehrenbergii* Schwein. (6,10). The fiber extracted from this species was coarse and the plant recovery after harvest was poor. These factors, along with the increased expense of gathering the leaves from greater distances in subsequent harvests, led to the failure of the industry in Africa. A small industry exists at present in Yucatan, Mexico, where both cultivated plants and wild stands of *Sansevieria guineensis* Willd. are harvested. Small amounts of the fiber are exported from Mexico to the United States annually (7). The lack of suitable mechanical harvesting and processing equipment has retarded the development of any large recognized sansevieria industry (3).

Prior to the initiation of the research program in Florida, little information was available in the literature regarding genetic behavior, cultural requirements and fiber quality of the various species of *Sansevieria*. Most of the literature dealt with taxonomy and with the botanical description of the species. Little had been done to improve the crop through selection or hybridization.

Sansevieria was probably introduced into Florida about 1800 during the Spanish colonization. Dodge (5) observed in 1892 that sansevieria grew well on both the lower east and the west coast of Florida. The plant was soon called "snake plant," or "mother-in-law's tongue," in the United States. In 1934, Mayo (8) commented on sansevieria as follows: "The fibre is capable of being manufactured into anything . . . from the heaviest cordage to the finest fabric for dress goods and is considered equal to many of the finest silks in beauty and fineness of texture. It is one of the most valuable of all fiber bearing plants and is thoroughly adapted to the soil and climate of Florida." Some readers may consider this an optimistic statement, but perhaps more attention should have been given to the investigation of sansevieria as a potential crop in Florida.

At the outset, the agronomic research program in Florida consisted of the introduction of new species, adaptation studies, propagation methods, fertility requirements and weed-control procedures. Wide differences were found between the various species in propagation habit, leaf type, rate of growth, cold tolerance, percent fiber and yield and quality of fiber. *Sansevieria trifasciata* Prain appeared to possess the best growth characteristics and to be well adapted to Florida. This species is somewhat cold-tolerant and easy to propagate from leaf cuttings and produces a dense growth in a short time. Weeds can be controlled in this species by the use of selective herbicides.

The *Sansevieria* genus is made up of species adapted to both mesophytic and xerophytic conditions. Some species tolerate intermittent flooding and even withstand hurricanes with comparatively little damage while others exist under arid conditions. Studies in Florida indicate that sansevieria prefers a neutral soil and is a heavy feeder of potassium, nitrogen and calcium. The fiber is finer and stronger than sisal or henequen and is finer than abaca and nearly as strong.

S. trifasciata requires a minimum of 3 years' growth before an economical harvest can be made. Experiments have indicated that

additional years of growth resulted in increased fiber yields. For example, material harvested after 2½, 3½, 4½ and 5½ years of growth produced 1,300, 4,000, 8,500 and 9,600 pounds of dry fiber per acre, respectively. After about 2 years' growth leaves of the *S. trifasciata* reach their inherent length, and therefore the increase of yield with age is due to the growth of new leaves (3). The production and rapid growth of new leaves of certain species is enhanced by the shading effect of the stand.

The necessity of waiting for 3 years for the first harvest of *S. trifasciata* limits the growth of this species in south Florida to areas where severe damage by cold does not occur. On Everglades muck damaging frosts can occur frequently enough to limit the successful growing of this species. One of the most important objectives of the research program in Florida was to develop a variety that was superior in yield, fiber quality, growth rate and cold tolerance.

In the early stages of the work, many clones and seedlings were selected among the most promising species available. Little progress was made by this selection. Many intervarietal and interspecific crosses were made. The most productive part of the breeding program was the development of hybrids by crossing *S. trifasciata* with *S. deserti*, N. E. Br. The latter species, a native of arid Africa, a poor propagator and an extremely low yielder, did possess some cold tolerance. The interspecific hybrids displayed much vigor and were more cold-tolerant than *S. trifasciata*. In tests conducted on Everglades peat, the hybrids planted in April 1956 with leaf cuttings produced a harvestable crop in 18 months. Low temperatures that occurred during the winter of 1956-57 had little adverse effect on the yield, because leaves harvested for fiber were produced during the subsequent frost-free period. This indicates that rapid-growing hybrids can be grown in the Everglades. The best hybrid in these tests produced about 3,000 pounds of fiber per acre from leaves 24 inches or more in length. By comparison, *S. trifasciata* and *S. deserti*, the parent species, produced about 600 and 200 pounds of fiber per acre, respectively. The hybrid produced more than twice as much as the better parent on the basis of total green weight including short and long leaves. The hybrids appeared to be easier to decorticate and produced significantly stronger fiber than either parent.

The results of the sansevieria research program, carried out cooperatively by the U. S. Department of Agriculture and the Florida Agricultural Experiment Station, have improved the general outlook for sansevieria.

More attention needs to be given to the production of improved varieties with higher fiber content and greater cold tolerance, a more economical method of weed control and the development of a suitable mechanical harvester. Owing to these limitations, sansevieria is not recommended for commercial production in Florida at this time. It seems likely, however, that sansevieria will find a place in the economy of certain Latin American countries, where a source of relatively inexpensive labor is available and where frost-free conditions exist.

Most hard fibers are grown in the underdeveloped areas of the world. The standards of living of these less fortunate people must and will be raised. When this becomes a reality, price of fiber will

increase and will result in the shifting of the areas of production. A sound sansevieria research program has been established and considerable knowledge is available to potential producers and processors in the United States and other countries.

BIBLIOGRAPHY

1. Anonymous. Foreign Agriculture Circular, FVF 3-58, 9-12-58.
2. Abbott, Fred P., The outlook for a pilot plant sansevieria project in south Florida. Proceedings of Soil Science Society of Florida, Vol. XI, 1951.
3. Crane, Julian C., Fiber content in relation to length and age of Sansevieria, Thunb. leaves. American Society of Agronomy, Vol. 37, No. 11, 1945.
4. Byrom, Mills H., Progress with long vegetable fibers. Crops in Peace and War. U. S. Department of Agriculture Yearbook of Agriculture. 1950-51, Pages 472-476.
5. Dodge, Charles R., "Report of the Secretary of Agriculture, 1892," U. S. Department of Agriculture, Washington (1893). Various fibers.
6. Gangstad, E. O., *et al.* Potentialities of sansevieria for fiber production in south Florida. Proceedings of Soil Science Society of Florida. Vol. XI, 1951.
7. Matthews' Textile Fibers, 6th Edition. Page 424. John Wiley & Sons. 1954.
8. Mayo, Nathan. Florida State Department of Agriculture. New Series 72-8-1934.
9. United States Department of Agriculture, Bureau of Agricultural Economics Market Research Report 51. (Fibers) 6-1953.
10. Wigglesworth, Alfred. The Hard Fiber Industry. Journal Royal Society Arts, 79 (4087): Pages 423-444. 1931.

Some Disease Problems Related to Hard-Fiber Production In Florida and Elsewhere[1]

T. E. Summers[2]

During the past several years an effort has been directed toward the development of domestically grown fiber plants which might, in an emergency, substitute for imported fiber. Among the problems encountered are diseases. I shall briefly mention the diseases that occur in areas where the crops are produced commercially and discuss in more detail those affecting experimentally grown fiber plants in Florida.

IMPORTED FIBERS

In importance, abaca (manila hemp) probably ranks first as the hard fiber which might possibly need to be replaced by a domestically grown cordage fiber. Mosaic and "bunchy-top" (virus diseases) are the most important diseases of abaca. Fusarium (Panama) disease and the Cercospora leaf spot are also important, but Helminthosporium stalk rot and other minor diseases have received little attention.

Sisal is affected by a number of diseases including a Fusarium stalk (bole) rot which has occurred in Florida, Venezuela and the Dominican Republic. A leaf spot caused by *Colletotrichum agave* may be serious. Sisal is subject also to sun-scald and deficiency induced diseases.

Henequen is subject to a boron deficiency disease and Colletotrichum and Diplodia leaf spotting.

SANSEVIERIA

A rather serious outbreak of bacterial soft rot and Fusarium petiole rot developed on *Sansevieria trifasciata* in 1953 at Fort Lauderdale and Belle Glade. Later plants at the Hays Farm near Lake Worth became diseased. Factors which contribute to heavy bacterial infection are mechanical spread by hand cultivation, exposure of plants to excessively low temperatures and direct exposure of leaves to sunlight under certain conditions.

A Fusarium-caused leaf spot, common on ornamental sansevieria in northern greenhouses, is also common in Florida in field plantings. The spots may remain small rather inconspicuous reddish circular

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[1]Research work conducted cooperatively by the Crops Research Division and the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Everglades Experiment Station of the University of Florida Agricultural Experiment Station, Belle Glade, Florida.

[2]Plant Pathologist, Agricultural Research Service, U. S. Department of Agriculture, Belle Glade, Florida.

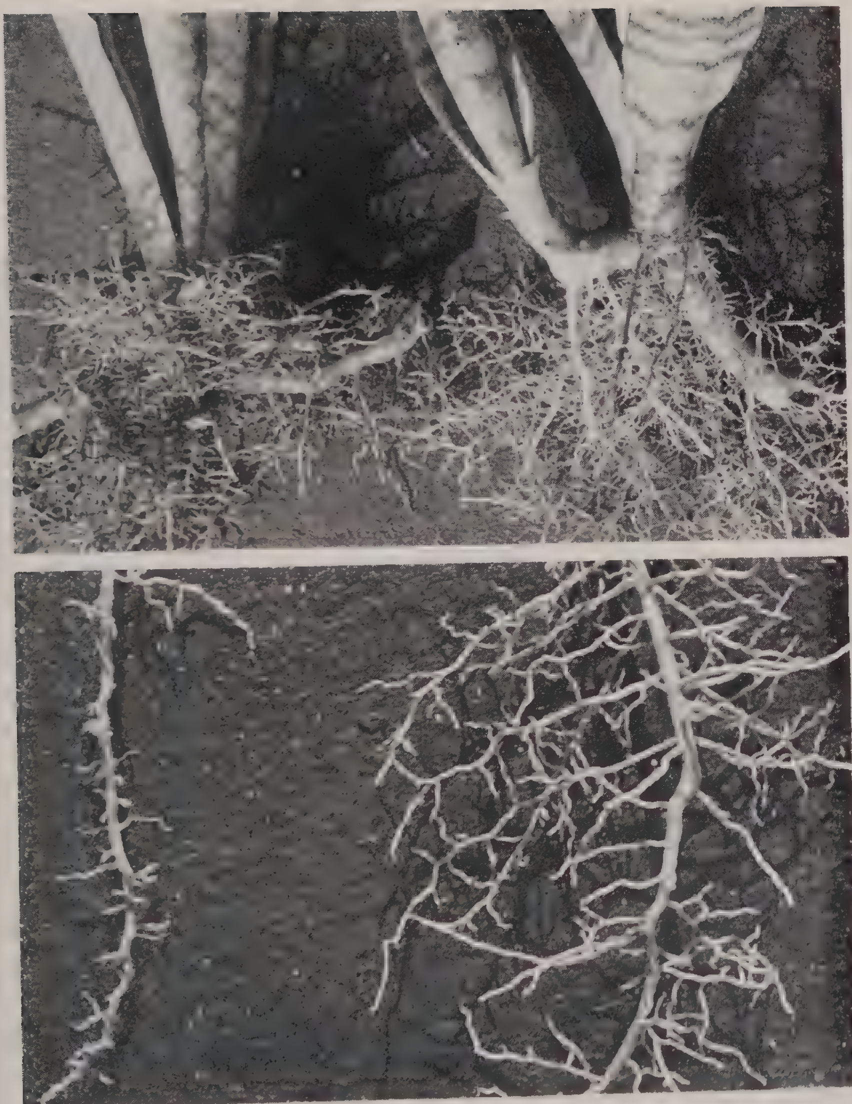

Figure 1.—Above—plant and root system of yellowed plant (left) and healthy green plant (right).
Below—representative individual root from yellowed plant (left) and from healthy green plant (right). Note absence of rootlets on root to the left due to decay.

sunken lesions or may become larger and more irregular under conditions favorable for its development.

A leaf spot caused by *Gloesporium sansevieriae* may in its initial stage resemble the fusarium leaf spot except for color, which is brown or almost black, and the spots generally become larger.

Disorders directly or indirectly induced by cold, wind, drought,

Figure 2.—Sansevieria hybrid plants (center and foreground) affected by rhizome and crown rot and root-knot nematodes (*Meloidogyne incognita acrita*).

nutrient deficiencies, chemical injury and physiologic unbalance may be very serious.

During the late spring of 1957, plants in large areas of a planting of *Sansevieria trifasciata* Prain near Lake Worth turned yellow and ceased to grow. This condition persisted all during 1957 and into 1958. Upon close examination, the tips, entire leaves or entire plants were seen to be yellow. In some cases these plants exhibited leaf spots, and in a few instances the leaves were decayed at the base of the petiole. The yellowed plants had decayed roots with few feeder rootlets attached to the branch roots (Figure 1). Isolations made from diseased roots always yielded *Aspergillus* sp., whereas isolations made from roots of green healthy plants did not. It has not been definitely established whether the fungus was the cause of the death of the roots or the indicator that the roots had already been killed or weakened. Since nematode galls were found on many of the diseased roots, there may be some association between the nematodes and the fungus.

In 1956 one hybrid sansevieria clone located at the Hays Farm was affected by a rot at the base of the plants. The disease spread to four clones in 1957, and the plants in a number of clones had been infected by early 1958 (Figure 2). Organisms associated with this condition were the root-knot nematode, *Meloidogyne incognita acrita*, a fusarium in the Liseola section, probably *Fusarium moniliforme*, and a bacterium. Decay of the underground rhizome accompanied the advanced stage of the basal rot.

Harvesting and Decorticating Sansevieria

Robert E. Hellwig and Mills H. Byrom[1]

The engineers and plant scientists of the Agriculture Research Service, United States Department of Agriculture, in cooperation with the Florida Agricultural Experiment Station have been conducting research on sansevieria. The objectives of engineering research and development of harvesting and decorticating machinery are to mechanize the production of sansevieria fiber to the extent that it would be economically feasible to establish a commercial industry in the continental United States. The growth characteristics of the sansevieria varieties available confine the potential area in North America to South Florida.

The ultimate objective is to develop fiber machinery that will decorticate the fiber in the field. The means toward this end has been to develop separate units, harvesting machinery and decorticating machinery and to attempt to combine the operations in a field machine later.

Satisfactory planting machinery has been developed for establishing plantings on a production basis and engineering research is concentrated on harvesting and decortication.

HARVESTER DEVELOPMENT

A sansevieria harvester was needed to cut, gather, and pack the fiber leaves in convenient crates or bundles for delivery to a decorticating plant. The first obstacle of this objective was the cutting device. Three basic designs were considered for cutting; (1) the scuffle hoe; (2) the cutter bar; and (3) a rotary saw or knife.

A harvester was built and tested using three scuffle hoes mounted at the end of a 36 inch pitman rod. The pitman rods were fastened to a three arm crankshaft so that the hoe reciprocated in the direction of travel at a rate of 90 fpm. Each hoe floated separately with a double acting hydraulic cylinder controlling the minimum height of cut. This floating characteristic permitted the hoe to follow the contour of the ground. The cut fiber was to slide over a plate to a 14 inch conveyor and compress in a chute so that all of the cut fiber was held in an erect position. A box 2 x 3 x 2 feet was placed at the end of the chute to catch the leaves.

The scuffle hoe cutting device appeared to work very well, however, the method was set aside because of other obstacles. The leaves were cut clean when cut at ground surface, but the leaves would fall down on the slide plate and build up in front of the conveyor until the machine stalled. Any leaves that were conveyed through the chute

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were lying down instead of being erect as planned. Several field trials were made without much success in regard to transfer of the leaves from the cutting device to the gathering system.

The harvester will be redesigned to utilize a cutter bar type cutting device. The basic principle of cutting, gathering in a chute, and packing in a box will be retained.

Previous studies of a cutter bar have been made with a tractor-mounted mower. The cutter bar rode up on the cut stubble and the cutting height gradually became higher until it was sliding completely over the crop. Weight added to the end of the bar failed to control the height of cut.

Several factors that affected the efficient operation of the standard cutter bar were:

(1) The forward speed of the tractor could not be reduced enough to permit a clean cut in the heavy growth of sansevieria,
(2) The shape of the mower guards pushed the plant down ahead of the cutter bar, and
(3) The control of the height of cut on one end of the cutter bar did not permit close enough control on the cutter bar.

The sansevieria harvester will be redesigned to overcome the difficulties experienced with the tractor mounted mower. The cutter bar will be 24 inches long mounted as part of the gathering conveyor. The height of cut will be controlled by a double acting hydraulic cylinder raising and lowering the entire chute and cutter bar. The mower guards will be stub nosed with the sickle sections extending past the nose about ⅜ inch.

Studies have not been made of the rotary blade or saw method of cutting.

DECORTICATING MACHINERY

The raspador type decorticator is used universally in areas where sansevieria is decorticated mechanically. The raspador decorticator consists of bars mounted on a rotating drum working against a bed plate with close clearance between the scraping bar and the bed plate. The clearance required for sansevieria ranges from .010 to .025 inch depending upon the variety.

The engineering research has involved the improvement of the shape of the drum, knife, and feed method. No other method of decortication of sansevieria has been explored thoroughly.

A review of United States and Mexican decorticating machinery patents was made in 1913 by Agricultural Engineers of the USDA. Observations were made in Merida, Yucatan, Mexico, of machinery operating on henequen. Plans and specifications were drawn up for a raspador machine with the following salient features.

(1) Two decorticating wheels 56 inches in diameter and 16 inches face operated against bed plates 40 inches long.
(2) The decorticating wheels were mounted on ball bearings and were designed for adjusting the minimum clearance between the decorticating wheel and bed plate to .001 inch.
(3) The decorticating wheel was equipped with 12 knives made of

brass with wood blocks in front of the knives to lead the fiber over them.

(4) The gripping device consisted of metal paddles attached to a roller chain working against a similar chain to hold the leaves during passage through the decorticator wheels.

(5) The decorticating wheel and grip mechanism were powered with separate variable speed drives with a range in speed on the wheels of 100 to 550 rpm and range on the gripping device of 30 to 90 fpm.

Two basic defects in the original gripping device led to a redesign of the grip: (1) the gripping device did not hold the leaves tight enough to prevent some of the fibers from pulling out of the grip and (2) the capacity was limited by the grip chain pulling into the decorticating wheel when overloaded.

The decorticator was remodeled as an in-line machine with co-acting grip-pads 4 inches wide and 6 inches long mounted on roller chains. The decorticating wheels were offset so that the leaves passed through first wheel and the fiber was transferred to the second gripping device to hold the decorticated end of the leaf and carry the undecorticated portion of the leaf through the second wheel.

Several changes have been made in the knives on the decorticating wheels. The latest design has proved to be the most satisfactory; the knife blades have been decreased from a 3½ inch width measured along the diameter of the wheel to a ¼ inch width with little change in efficiency of the fiber recovery and the latter design has shown a definite improvement in the cleanliness of the fiber. The number of knives was increased from 12 to 24 which improved the cleanliness of the fiber.

The USDA decorticator when operated at 400 rpm on the decorticating wheels, and fed at 60 fpm on the feed table has produced approximately 150 pounds of dry fiber an hour. The percent recovery of fiber has ranged between one to two percent of the green weight depending on the variety, length, and condition of the leaves.

The use of an abundance of water on the decorticating wheels as the fiber passes through the machine decreases the loss slightly and results in a cleaner fiber.

The research done by the Cotton and Cordage Research Branch indicates that four year old *Sansevieria trifasciata* will yield approximately four tons of dry fiber per acre. The rate of recovery of *S. Trifasciata* on the USDA decorticator has averaged about 1.5 percent which indicates that commercial production may be feasible.

SMALL DECORTICATORS

There are a number of hand decorticators in use in countries where sansevieria is being produced. The economic production of sansevieria on the hand machine limits the area of production to countries with an abundance of cheap labor.

The United States Department of Agriculture has a Japanese decorticator patterned after the French Patent "Faure" which is excellent for decortication of small samples. The design of this machine is also based on the raspador principle.

SUMMARY

Engineers and plant scientists of the Agriculture Research Service, USDA, in cooperation with the Florida Agricultural Experiment Station have been conducting research on sansevieria. The design of a harvester is in the development stage which should cut, gather, and pack the sansevieria leaves in crates for delivery to the decorticator or feed the leaves into the decorticating wheels of a field machine. The research on decorticators has progressed satisfactorily using the raspador principle and improvement of the decorticating knives and feeding mechanism. The ultimate objective will be to combine both machines into a single field unit.

REFERENCES

1. Byrom, Mills H., Progress with Long Vegetable Fibers. Yearbook of Agri-
2. Dewey, Lyster H., Fiber Production in the Western Hemisphere, Miscellaneous Publication No. 518, USDA, 1943.
3. Weindling, Ludwig, Long Vegetable Fibers, Columbia University Press, New York, 1947.
4. Robinson, Brittain B. and Falba L. Johnson, Abaca, A Cordage Fiber, Agriculture Monograph No. 21, USDA, 1953.
5. Tobler, F., Extraction of Leaf Fibers, Ciba Review, August 1953, p. 3565.
6. Brases, Andres Castells, Cultivo de la Cabuya y Beneficio de sus Fibras, Quite Editorial Colon, 1939.
7. Mesa A., Manuel y Rogelio Villanueva V., La Production de Fibras Duras en Mexico, 1948.

Mechanization of Brush Fiber Production

Mills H. Byrom and Hiram D. Whittemore[1]

INTRODUCTION

The use of brushes by mankind probably dates back to the beginning of civilization when bunches of twigs were used to sweep out living quarters. It is doubtful if many realize the important place that brushes have come to occupy in our modern way of life. From the dainty Camel hair brush used by the artist to give just the right expression to the subject he paints, to the massive steel bristle brush used to polish steel plates, and the stiff bristled rotary brush used to clean the roads and streets of our modern cities, brushes contribute to better living in the present age.

We use a brush on our hair, a brush for our teeth, another for our hat, another for our clothes, two or more for our shoes; the wife uses a brush to spread shortening on the pastries as they come from the oven, another to scrub the vegetables before they are cooked, and another to scrub the floor.

The carpets and the furniture are cleaned with a brush, the floor is waxed and polished with a brush; and the walls and ceilings are dusted with brushes. These are but a few of the many uses around the home for brushes. A large number of industrial uses are found for brushes in cleaning, polishing and preparing products for the market.

TYPES OF MATERIALS USED IN BRUSH MAKING

Brush bristles made of steel, bronze or other metal wire, nylon, vinyl type polymer, polysterene and many other similar materials are finding an important place in the brush making industry. Animal hair, particular hog bristles for paint brushes and horse hair for a variety of brushes, have been in favor for many years.

Important as the above products are in the brush making industry, they have not materially reduced the demand for natural fibers as a source of brush bristles and this paper will deal mostly with the production of these fibers from the plant.

There are three groups of vegetable fibers that have been used extensively in the manufacture of brushes. These are Palm leaf fibers, the Ixtle fibers (Agaves and Yuccas) and the whisk or root fibers.

PALM FIBERS

Bahia Piassava (Attalia Furifera) is secured from Northern Brazil. Some of the fiber projects from the back of the leaf stem and can be pulled out by hand. After these have been extracted the stem is water

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retted and subsequently hammered, scraped and combed to free the fibers from foreign material. The dried fiber is roughly graded according to fineness and length and bundled or baled for shipment. The fiber is further dressed in the factory before it is ready for use in road sweeping and other heavy duty brushes.

Bassine or Palmyra (Borassus Flabellifera) fiber comes from Ceylon and India. Different grades are produced from the leaf spathe or boot, from the peduncle and from the mid rib of the leaf blades. The preparation of Palmyra or Bassine before it reaches the factory is entirely a hand operation.

Palmetto fiber is obtained from the Sabal Palmetto or cabbage palm. At one time there were six plants in Florida that collected material from the native growths and extracted the fiber. At the present time only two of these are active. The fiber is obtained from the boot or spathes surrounding the terminal bud. These are steamed under pressure to soften the non-fibrous material which is loosened and removed by rolling and hackling. The fiber produced is excellent in quality, but is more expensive than other fibers used for the same purpose.

Coir or Coconut fiber was once an important brush fiber in the United States but due to lack of uniformity it has been all but entirely replaced by other better and cheaper fibers. Coir is produced by retting the husks from the coconut in salt water for 3 months or more. They are then pounded and hackled on a revolving spiked drum.

THE WHISKS

Zacaton (Muhlenbergia Macronra) a long slender root fiber, Italian and Hungarian whisks (Andropogon) and American broom corn (Sorghum Vulgare) are used to some extent in making whisk brooms and coarse brushes. A great deal of hand labor is used in producing these fibers. If demand increased, some of the production could be mechanized.

THE IXTLE FIBERS

Like Piasava and Palmyra, the Ixtle fibers are produced from plants growing in the wild state. The ixtle group is composed of fibers commonly known as Pita, Palma, Tula and Jaumave.

Pita and Palma are obtained from Yuccas. The pita fiber is extracted from the center bud or cogollo of Yucca *trucyleana* while Palma come from Yucca *Samuela Carnerosana*. These fibers are soft and lack the life and resilience needed in a good brush fiber. They are used mostly for bags and similar materials instead of jute.

The leaves are boiled and steamed to soften the tough outer skin and the pulp surrounding the fibers. They are then cleaned by hand scraping in the same manner as the tula and jaumave fibers.

Tula is the fiber that comes from Agave Lecheguilla and is the coarsest and toughest of the Agave fibers.

Jaumave fiber is produced from Agave *funkiana*. It is longer, finer textured, lighter in color and more uniform than the tula fiber.

Agave lecheguilla is indigenous to the semiarid, rocky hillsides extending from south west Texas and New Mexico across northern Mexico and southward to San Luis Potosi. Agave *funkiana* grows only in the mountain ridged Jaumave Valley of Mexico.

All commercial production is by hand scraping from plants growing in the wild state. Only the leaves from the cone shaped center bud or cogollo are scraped. The outer leaves are green in color but the inner ones are creamy white. The scraper or tallador as the Mexicans call him uses the following tools or equipment in his work:

1. The arrancador—a steel ring or loop about 1½ inches in diameter fastened to the end of a pole or rod, usually a mesquite limb an inch or more in diameter and 3 to 5 feet long. Longer poles are used on the taller yucca plants. In operation the ring is slipped over the Cogollo and given a deft twist which breakes the leaves at their base. In about six months a new cogollo is produced and is ready to be harvested.

2. Haujaca—a basket woven by hand from lecheguilla fiber fitted to a bent limb of a mesquite. This crude basket is fitted with a harness made also by hand from lecheguilla fiber to fasten the basket on the operators back. As the cogollos are extracted from the plant they are placed in the haujaca. When the basket is filled, the tallador hunts the nearest shade and sets about scraping the leaves.

3. El bolillo—a round stick, 3 or 4 inches long and ¾ to 1 inch in diameter used to aid in holding the leaf as scraping proceeds.

4. El banco—a hard wood block usually hewn from a mesquite limb, 12 inches long, 4 inches wide and about 2 inches thick.

5. El tallador—A crude dull knife having a point on one end and a handle on the other.

In operation, el banco is placed on a level spot of ground and a peg driven down beside it. El tallador is placed over el banco and its point inserted in a hole in the peg. This acts as a fulcrum by which pressure for the scraping operation is secured. El bolillo is placed in one end of the leaf and grasped in one hand. The free end of the leaf is drawn between the knife edge and the block. One or two deft strokes removes all of the waste material. When one end of five or six leaves have been cleaned the fiber ends are twisted around the bolillo to obtain grip and the other end is cleaned. When a small bundle of fiber has been scraped, it is spread across a stick or tree branch where it is dried and bleached in the sun.

The fiber yield from the cogollos is low, usually less than 5 percent. A good scraper can produce about 40 pounds of crude fiber per week.

NEED FOR MECHANIZATION

Fiber scraping is very hard work and the caustic juices of the lecheguilla plant are hard on the operators hands. For the above reasons coupled with the very low remuneration, the Mexican peon scrapes fiber only when there is no other means of securing the small amount of cash needed to keep his family going.

There has been a great number of machines designed to decorticate ixtle fibers, but due to the difficult terrain, lack of power, scarcity of water, inability of the peon to operate such machinery, and other

factors none of these machines have been adopted for commercial production. To further discourage the use of machinery there has been a widespread belief that mechanical decortication damages the fiber to the extent that it is not servicable for use as brush bristles. Recent shortages of hand scraped tula and jaumave fiber have renewed the interest in mechanical decortication. Although committed to a policy of retaining ixtle fiber production as a hand operated industry for the peon class of laborers, the Mexican government agency, "La Forrestal" which controls the marketing and exporting of the fiber has recently been investigating small portable decorticating machinery which they hope the La Forrestal will approve and permit its use in Mexico.

In view of a considerable acreage of wild plants growing along the Texas and New Mexico borders, the U. S. Department of Agriculture set up a project to investigate the possibility of producing fiber and extracting some of the chemical products such as smilaganin and perhaps wax from the agave lecheguilla plant by mechanical means.

In order to determine the extent of injury to the fiber in mechanical decortication, a small quantity of cogollos and also mature leaves were secured from plants in West Texas. Some of each were hand scraped by a regular tallador in Mexico, and the remainder decorticated on the small "Faure" decorticator in the fiber laboratory at Belle Glade, Florida.

Tensile strength, wear and flex tests made in the laboratory at Belle Glade showed the mechanically decorticated fiber equal in every way to the hand scraped fiber. Examination by technicians in industry also showed no damage due to mechanical treatment.

On the basis of these tests, a portable machine of the raspador type was built and mounted on a farm wagon equipped with heavy duty trucktires in order to transport it over the rough, rocky terrain where lecheguilla grows. A triple roll crusher was built to reduce the plants to single leaves. This was operated separate from the decorticator in the initial tests. A box car load of plants from West Texas was used in adjusting and testing both units before they were sent to the field. The crushing rolls were completely redesigned and mounted on the feed table of the machine giving a composite unit. It was found that the leaves after crushing were not well enough aligned to give satisfactory results but manually arranging them before they got to the decorticator seemed to work well enough for a field trial. The machine was sent to West Texas where further work was done in testing a wide variety of crushing and feeding devices. Drying problems were also studied.

The crushing feeding device developed as a result of these tests consists of a pair of crushing rolls made of 12" standard pipe. They are 30 inches in length and are mounted in a square tubular frame so that the space between them can be adjusted to care for plant size and other operating conditions. Three pairs of No. 55 hook chains pass through the rolls forming grip chains in which the whole plants are fed. A circular saw, 16 inches in diameter severs the root part of the plant, facilitating separation of the leaves with very little fiber loss. As the chains move through the rolls, the bulbous part of the plant is crushed flat, thus freeing the individual leaves and mashing them

out into a flat blanket in which condition they are presented to the grip chains of the decorticator, well butted and in condition to pass on through the decortication process.

The feeding rolls as well as the decorticator are still undergoing tests and are being modified and improved to correct sources of fiber loss and also to correct mechanical weaknesses.

Recent tests showed a dry fiber recovery of 5.2 per cent based on total weight of green plant material fed to the machine. A capacity of 234 pounds of dry fiber per hour was secured.

This performance is considered satisfactory but further improvements in the entire plant harvesting, feeding, decorticating and drying are needed if mechanical production is to compete with hand scraped fiber.

It is hoped that by-products will carry part of the expense and thus make mechanical production of lecheguilla fiber economically feasible on a commercial scale.

REFERENCES

1. Dewey, Lyster H., Fiber Production in the Western Hemisphere, U. S. Dept. of Agriculture, Miscellaneous Pub. 518, 1943.
2. Weindling, Ludwig, Long Vegetable Fibers; Columbia University Press, 1947.
3. Slack, E. B., Coarse Fibres, Wheatland Journals, Ltd. 1957. London, England.
4. Mesa A., Manuel y Rogelio Villanueva V., La Produccion de Fibras Dura en Mexico, Monografias Industriales del Banco de Mexico S. A., 1948.
5. Bailey, L. H., Manual of Cultivated Plants, The MacMillan Company 1954.
6. Unsworth, Herbert, Production of Ixtle Fiber, A Mimeographed Monograph Fibras Duras, Monterrey, Mexico.
7. E. B. & A. C. Whiting Company, Burlington, Vermont Leaflets:

    (1) Gathering and Scraping Ixtle Fiber
    (2) Ixtle de Palma
    (3) Bahia Bass Fiber
    (4) Fibre and Fibre Mixtures.

FIBER CROP SYMPOSIUM—THE PRODUCTION AND PROCESSING OF SOFT OR BAST FIBER

Strength and Fineness of Ramie Fiber[1]

C. C. SEALE AND R. V. ALLISON[2]

The fiber of ramie (*Boehmeria nivea* (L.) Gaud. and *B. utilis* Blume) is located in the bast of the plant (11,12). The mature plant contains about 1.50 to 6.50 percent fiber in the green stalk, depending on the variety, soil, and climatic conditions (11). The fiber is extracted from the stalk by a mechanical process of decortication (6,8, 11). The gums and natural encrustants that adhere to the crude fiber after decortication are generally removed by a chemical process of degumming (4,6,7).

Of all the bast fibers, ramie is the most highly cellulosic in character, and is the least lignified (12). The fiber is very strong and durable, and resists disintegration better than most of the natural fibers when exposed to the weather or when immersed in water (8 12). It tapers at both ends, and unlike cotton, does not possess convolutions (9). Microscopic studies have shown considerable variation in the cross sectional size and shape of fibers from different ramie varieties (3). The fiber varies in length from 4 to 16 inches, and in diameter from 40 to 60 microns (12). The maturity of the fiber can be determined by a differential dye test (2).

Ramie fiber can be blended with many natural and synthetic fibers, and can be used in the manufacture of many types of fabrics, upholstery, firehose, fishnets, and many other products (7,11). Whether spun alone or as a blend with other fibers, the fineness of ramie fiber is very important.

For accurate testing of quality, the separation of the individual fibers must be complete (9), and test samples must be thoroughly degummed and properly combed or carded.

Preliminary tests of ramie indicate that strength and quality vary with variety, maturity of the plant, environmental and cultural conditions, and method of preparation (6). As the fiber becomes more mature in the plant, tensile strength increases, while flex declines. Knot strength or shear is considerably lower than tensile strength. Wear shows a continuous decline with age (3). After comparison with test procedures for cotton, a suitable method has been determined for testing fineness of ramie fiber (9).

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[1] The research work on which this paper is based was conducted cooperatively by the University of Florida Agricultural Experiment Station, the Crops Research Division and the Agric. Engineering Research Division, A.R.S., U.S. Department of Agriculture.

[2] Associate Agronomist and Fiber Technologist, respectively, University of Florida Everglades Experiment Station, Belle Glade, Florida.

EXPERIMENTAL PROCEDURE

Since the establishment of the fiber laboratory at the Everglades Experiment Station in 1948, samples of degummed ramie fiber have been tested for tensile strength, knot strength, abrasion resistance and flexual endurance, more commonly known as strength, shear, wear and flex, by the methods of Schiefer (10) and Berkley et al (5). In preparation for making these tests, fiber bundles 15 inches long weighing 325 milligrams were drawn from the sample. In the strength test, five breaks were made on two fiber bundles per sample; while in the shear test, two breaks were made on five bundles per sample. The wear test (ss twist) was made with three bundles per sample abraded in the test machine against a steel wire. The flex test was also made with three bundles per sample.

TABLE 1.—Strength, Shear, Wear and Flex of Ramie Varieties Grown on Everglades Peat in 1950-55 and Tested in the Fiber Laboratory, Belle Glade, Florida.

Variety	Strength 1000 p.s.i.	Shear 1000 p.s.i.	Wear, cycles	Flex, 1000 cycles
B. nivea E. 53-41	80.4	27.9	62	12.7
B. nivea E. 51-78	77.6	32.4	55	11.0
B. nivea P.I. 87521	76.4	26.5	308	42.3
B. nivea P.I. 205500	66.4	35.5	65	18.4
B. nivea Lembang	53.0	28.1	287	93.4
B. nivea P.I. 70791	43.2	26.2	166	51.8
B. utilis P. I. 205502	56.3	23.2	52	12.7

During the period 1952-55, before facilities were available for testing the fineness of ramie fiber in the fiber laboratory at Belle Glade, arrangements were made with three foreign fiber laboratories (Ernest H. Fischer's Sons Ltd., Dottikon, Switzerland; Spinnerei und Zwirnerei Ramie A. G., Emmendingen, Germany; and Toyo Sen-I Co. Ltd., Tokyo, Japan) for the testing of 60 ramie variety samples for fineness of fiber. In most cases, denier determinations were made on fiber from the middle section of the stalk, but with a selected group of varieties this factor was also determined in the base and tip sections.

The fiber samples were prepared and tested in the Swiss, German and Japanese fiber laboratories in accordance with standard test procedures.[3]

Arrangements were made in 1956 for testing the fineness of ramie fiber in the laboratory at Belle Glade by a method outlined by Pearson (9). This method is a modification of a test procedure used with cotton in which about 105-110 ramie fibers are selected, cut to a length of 1 inch and weighed on a microbalance. From these data the fiber weight per inch in micrograms is computed, and the corresponding value of denier is determined by the use of an appropriate conversion factor.

[3]Private communications addressed to Dr. R. V. Allison, Fiber Technologist, Everglades Expt. Sta., Belle Glade, Fla. from Ernest H. Fischer's Sons Ltd., Dottikon, Switzerland, Spinnerei und Zwirnerei Ramie A. G., Emmendingen, Germany, and Toyo Sen-I Co. Ltd., Tokyo, Japan.

Samples of fiber of 25 ramie varieties which had been tested in 1956 for fiber fineness by the Pearson method (9), were subsequently tested for fineness by a modification of the Miconaire method (1). This latter method is designed essentially for the determination of the fineness of loose cotton fiber by measuring the resistance of a plug of this fiber to air flow under standardized conditions. In the Micronaire tests with ramie, slight modifications were made in the plug weight and operational pressure. The Micronaire values obtained in these tests were read on the cotton scale, as no scale for ramie has yet been established.

RESULTS

The strength, shear, wear and flex values of seven ramie varieties grown on Everglades peat during 1950-55 are presented in Table 1. These data illustrate the wide fluctuations that can be obtained in the fiber quality of ramie varieties. Variations in strength from 43.2 to 80.4 thousands of pounds per square inch were obtained. Shear values showed the least variation, and were on an average about 44 percent of the strength values. Wear and flex fluctuated to the greatest extent; the highest values of wear and flex were about 6 and 8 times greater respectively than the lowest values. When all factors are considered, a variety of *B. utilis* was poorer in quality than most of the varieties of *B. nivea*.

A comparison was made of the fineness of fiber of 60 ramie varieties in a Swiss, German, and Japanese laboratory. The results of these tests on a selected number of varieties having a wide range of denier values is presented in Table 2. These data show that the denier values obtained in the German laboratory are somewhat lower than those in the Swiss and Japanese laboratories.

From the results of the fineness tests in these three laboratories, mean denier values were calculated for each ramie variety. These values are plotted in a frequency diagram in Figure 1. This diagram shows that most of the ramie varieties fall within the range of 7 to 9 denier, with an average of 7.8 denier. Very few varieties had fiber that was either very fine (below 5 denier), or very coarse (above 10 denier).

A more complete analysis of the fineness of the fiber in the stalk was carried out on a selected group of ramie varieties in the Swiss laboratory. In this case, denier values for fiber were obtained from the base, middle and tip sections of the stalk. These results are presented

TABLE 2.—Comparative Fineness of Ramie Fiber Expressed in Denier as Determined in Three Foreign Fiber Laboratories.

Variety	Denier			
	Swiss	German	Japanese	Mean
B. nivea E. 47-36	5.8	4.7	5.1	5.2
B. nivea P.I. 87521	6.4	5.4	6.4	6.0
B. nivea E. 50-86	9.2	5.5	8.6	7.8
B. nivea E. 50-90	9.4	7.6	8.9	8.6
B. nivea E. 50-12	10.1	8.5	10.9	9.8
B. nivea E. 50-76	10.5	8.4	12.2	10.4

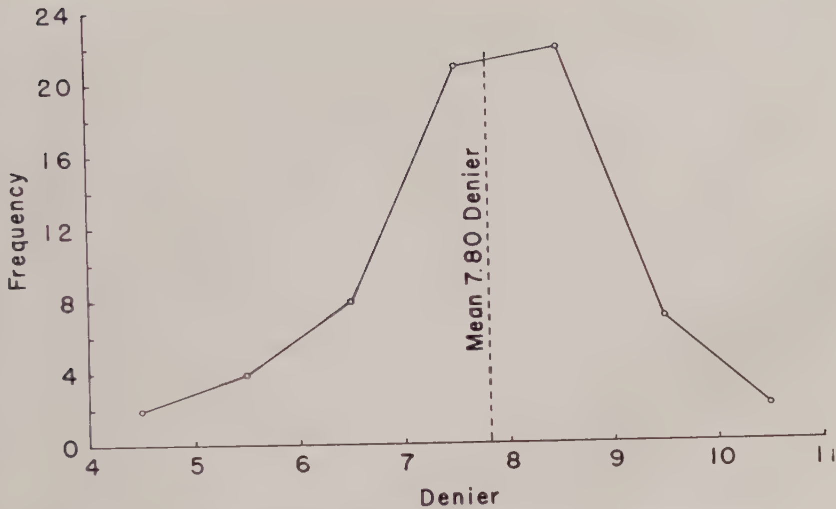

Fig.1– Frequency diagram for denier of ramie fiber

in Table 3, and show that there was a progressive increase in fineness of fiber in the stalk from base to tip. The mean values for the base, middle and tip sections combined correspond quite well with the middle section values, indicating that a test for fineness of fiber from the middle section of the stalk only would give a reliable index of the average fineness of fiber for the whole stalk. Furthermore, if fine denier fiber were in demand, it might be practical to separate the fiber of the tip section of certain varieties, and to handle this finer fiber separately.

From samples sent to the Japanese laboratory, the maximum, minimum and mean lengths of fiber of three varieties of *B. nivea* was determined. These data are given in Table 4, and show that there is little difference in the length of fiber of the three varieties. The average maximum, minimum and mean fiber lengths of the three varieties were about 13, 1.5 and 7 inches respectively.

After facilities were established in the fiber laboratory at Belle Glade for testing fineness of fiber, a group of ramie varieties, believed to have a wide range of denier values, were tested by the Pearson

TABLE 3.—Fineness of Ramie Fiber from Base, Middle and Tip Sections of Stalk as Determined in the Swiss Laboratory.

Variety	Denier		
	Base	Middle	Tip
B. utilis Mexico	5.9	4.8	4.4
B. nivea E. 47-36	7.1	5.8	3.9
B. nivea E. 50-83	6.9	5.9	5.8
B. nivea P.I. 87521	8.7	7.1	6.0
B. nivea E. 50-84	8.0	7.3	6.7
B. nivea E. 51-16	9.2	8.9	7.7
B. nivea E. 50-86	10.1	9.2	8.9

method (9). By this method, the fiber weight per inch in micrograms is determined directly, and the denier is derived by the use of an appropriate conversion factor. The results of these tests, which are given in Table 5, show a range of values in weight of fiber from 11.8 to 27.0 micrograms per inch, equivalent to 4.2 and 9.6 denier respectively. *B. nivea* Tatsutyama, an introduction from Japan, had the finest fiber, and *B. nivea* E. 51-65, an Everglades selection, had the coarsest fiber. By comparison, *B. nivea* P.I. 87521, a variety grown commercially in Florida, was intermediate in fineness.

Fineness of fiber of 25 ramie varieties grown on Everglades peat in 1954 was determined by both the Pearson and Micronaire methods. A regression of denier on Micronaire values was calculated, and the results are plotted in Figure 2. These data show a very high degree of correlation. The Micronaire method is comparatively rapid, and might be used in preliminary screening tests for fiber fineness of ramie varieties.

ACKNOWLEDGMENTS

The authors are indebted to Ernest H. Fischer's Sons Ltd., Dottikon, Switzerland, to Spinnerei und Zwirnerei Ramie A. G., Emmendingen, Germany, and to Toyo Sen-I Co. Ltd., Tokyo, Japan for testing samples of ramie fiber for length and fineness.

Acknowledgement is also made to Mr. Hiram D. Whittemore, Agricultural Engineer, Agricultural Engineering Research Division, U. S. Department of Agriculture for running the Micronaire tests, and to Mrs. Irene S. Doub, Physical Science Aid, Crops Research Division, U. S. Department of Agriculture for making the determinations on tensile strength, shear, wear, flex, and fineness of ramie fiber in the fiber laboratory at the Everglades Experiment Station, Belle Glade, Florida.

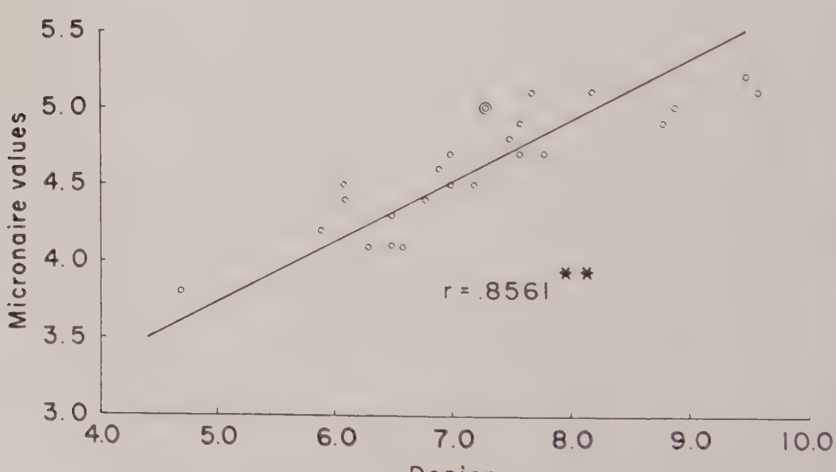

Fig. 2—Regression of denier on micronaire values of ramie fiber

TABLE 4.—Length of Ramie Fiber Grown on Everglades Peat, Near Canal Point, Florida.*

Variety	Length, Inches		
	Max.	Min.	Mean
B. nivea P.I. 87521	13.5	1.5	6.5
B. nivea Tatsutyama	13.0	1.5	7.0
B. nivea Saikeiseishin	13.0	1.5	7.1

*Determinations made in fiber laboratory of Toyo Sen-I Co., Tokyo, Japan on samples of ramie fiber provided by Mr. J. M. Dempsey, formerly Manager, Fiber Division, Newport Industries, Inc., Canal Point, Florida.

TABLE 5.—Fineness of Ramie Fiber Grown on Everglades Peat and Tested in Fiber Laboratory, Belle Glade, Florida.

Variety	Fiber weight, micrograms per inch	Denier
B. nivea Tatsutyama	11.8	4.2
B. nivea Kagisei	13.2	4.7
B. nivea E. 51-43	16.5	5.9
B. nivea P.I. 87521	18.3	6.5
B. nivea E. 50-66	19.6	6.9
B. nivea E. 50-49	20.5	7.3
B. nivea E. 50-43	21.3	7.6
B. nivea Murakami	22.1	7.8
B. nivea E. 51-71	23.1	8.2
B. nivea E. 51-72	24.7	8.8
B. nivea E. 50-12	25.2	8.9
B. nivea E. 51-65	27.0	9.6

LITERATURE CITED

1. Anonymous. ASTM Standards on Textile Materials (with related information). Amer. Soc. for Testing Materials. Nov. 1956. Philadelphia, Pa.
2. Anonymous. Dye does it. Agric. Research 4(7): 14. Jan. 1956.
3. Anonymous. Ramie production in Florida. A progress report prepared for U. S. Dept. Comm. by U. S. Dept. Agric. and Univ. of Fla. Agric. Expt. Sta. Pub. 97342. U. S. Dept. Commerce, Washington, D. C. 1948.
4. Allison, R. V. Ramie comes to stay in Florida. Chemurgic Digest 11: 14-16. 1952.
5. Berkley, E. E., Hessler, L. E., Burneston, E. B. and Chew, C. F. A study on the quality of abaca fiber. U. S. Dept. Agric. Tech. Bull. 999. Oct. 1949.
6. Byrom, M. H. Progress with long vegetable fibers. Crops in Peace and War. U. S. Dept. Agric. Yearbook of Agriculture 1950-51. pp. 472-476.
7. Gangstad, E. O., Seale, C. C. and Pate, J. B. Preliminary studies on the fiber quality of ramie varieties. Turrialba 4: 66-71. 1954.
8. Nelson, E. G. Ramie. Mimeo Rpt. COFCD-10. U. S. Dept. Agric. Feb. 21. 1952.
9. Pearson, N. L. Measurement of ramie fiber-fineness. Progress report. U. S. Dept. Agric. Textile School, Clemson College, Clemson, S. C. July 10, 1956.
10. Scheifer, H. F. Machines and methods for testing cordage fibers. U. S. Nat. Bureau of Standards Jour. Res. 33: 315-339. 1944.
11. Seale, C. C., Ganstad, E. O. and Joyner, J. F. Agronomic Studies of ramie in the Florida Everglades. Fla. Agric. Expt. Sta. Bull. 525. 1953.
12. Whitford, A. C. The bast fibers. Mathews' Textile Fibers. 5th Edition. 1947. New York, N. Y.

Harvesting and Processing Ramie in Preparation for Industrial Use

R. V. Allison[1] and John W. Randolph[1]

A remarkably interesting and useful book was published by the U. S. Department of Agriculture in 1897 as Report No. 9. Fiber Investigation with the title, "A Descriptive Catalog of Useful Fiber Plants of the World," under the authorship of Charles Richard Dodge. This is a volume of 375 pages that describes in excellent detail, for that time more than 1000 species of plants that produce useful fibers. The discussion of ramie in this book is given a total of six and one half pages and, even at that early date, contains much material that is altogether familiar with reference to the character and quality of this fiber as well as some of the principal problems related to its processing and recovery.[2]

Thus in a brief paragraph devoted to the extraction of the fiber we read in part as follows:

> "there are three ways in which the fiber of . . . . ramie may be extracted; by hand stripping, as practiced in China; by boiling the stalks in water or solutions, which also requires a certain amount of hand manipulation; and by machinery. The stripping by hand can only be made to pay where wages are down to the level of those paid in China, and almost the same may be said of boiling processes necessary to separate trash from fiber when the bark separation has been accomplished. As far as the Department has knowledge of new machines, this phase of the ramie question is still unsettled, though progress is being made from year to year as old machines are improved and new ones are devised."

Remember this was published in 1897! In any event when Mr. Dodge refers to "the large mass of literature on China grass" as in existence at that time it lends reluctance indeed to delving back into it and even into the detail of much that has happened since that time in getting at the brief summarization of what has been done more recently in undertaking to grow and develop this plant and process its really remarkable fiber in a manner that will fit it into our modern needs in a way economically compatible with the tremendous development that has taken place in the past few years in the production of man-made or "ersatz" fibers.

Inasmuch as the adaptability of ramie to our Everglades soil and climatic environment has been under study at the Everglades Experi-

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[1]Fiber Technologist and Agricultural Engineer, respectively, Everglades Experiment Station, Belle Glade, Florida.

[2]This volume, long since out of print, is now available from University Microfilms, Inc., 313 N. First St., Ann Arbor, Mich. with light paper cover at a very nominal price.—Ed.

ment Station since 1929 and has been reported on quite fully from the agronomic standpoint elsewhere, we will largely limit this quick review of the harvesting and processing of this fiber to what has happened and what progress has been made, even in the mechanical field, since 1943-44 and more particularly since 1954. This is for the reason that by the earlier date Newport Industries, Inc. of Pensacola had organized a ramie production project on a rather grand scale in the Everglades at Canal Point. This was a remarkable effort in many ways more especially, of course, thru the fact that it actually established ramie production on a commercial scale for the first time in Florida or, for that matter, in the Western Hemisphere.

Since there has been no particular question as to the growth of the plant other than rational fertilization and the best possible water control, the development of the project turned primarily on the harvesting of the crop and the extraction of the fiber that must follow almost immediately. This field harvesting operation was accomplished thru the use of such of the modified hemp binders they could find (a John Deere Deering rice harvester-binder adapted to the handling of hemp or rather plants 7-9 feet tall) as abandoned, mostly unused, equipment of World War I. The decortication or defibering of the stem on the moderately massive scale that quickly became necessary as the project developed was done with a properly modified Krupp-Corona unit originally designed for hard fiber plants such as sisal, abaca etc. that was built by the Mohegan Fiber Equipment Company of New York according to the specifications of Newport Industries officials.[1]

The area of the project was expanded quite rapidly from a very small beginning to about 2500 acres and most of the fiber was produced and baled for market as washed ribbons largely for export in that form to Germany, Switzerland, France, Japan and Italy. In fact those markets did not want stapled or degummed fiber as they preferred to degum by their own process in the form of full length ribbons. The product was so uniform within the grades that were established and was available in sufficient volume to rather quickly dominate the international market from the quality standpoint, at least for the time being. Mr. Harry Neiman of New York commented very strongly on the extreme heterogeneity of China grass on the world market at the time of the meeting of the Soil Science Society of Florida in Belle Glade in April of 1946 as reported in Proc. Vol. VIII of that Society, page 141-2 and, at the same time, gave much praise to the high quality of the Newport product, in comparison.

Inasmuch as there has been only a limited amount of spinning capacity in the United States in the linen or silk system prepared to use ramie in the length of staple commonly practiced in the countries mentioned above, comparatively limited effort was made to interest U. S. manufacturers during the period of most of Newport's operation which extended to the late autumn of 1956. This was largely because stapling of the dried fiber to the short lengths (1½" to 2½") required

[1]All of the past effort has been described in very clear detail in Mr. M. H. Byrom's Agriculture Information Bulletin No. 156, published in 1956 by the USDA under the title "Ramie Production Machinery." It was during the late autumn of that year that the Newport operation was discontinued.

by cotton spinning equipment could not be done with sufficient accuracy to allow all-ramie spinning in those lengths. In any event the fiber is so straight and smooth that yarns spun in these short staples could not show nearly the strength expected if strength were to be an important factor in the end use. With the progress of Mr. H. G. Morton's work in Florida as Industrial Consultant which spanned the discontinuance of the project by Newport Industries, the above difficulties were resolved quite largely by (1) working with the so-called American System on into the worsted and woolen systems of spinning and (2) blending with such synthetics as dacron which has greatly facilitated the handling of ramie on the cotton system even down to 1½" staple. Mr. Morton will doubtless dwell on these important points in requisite detail in a later paper on this same program.

For some time before Newport Industries Corporation discontinued its operation and was taken over by a locally developed company, Pierce Florida Ramie, Inc., it was generally felt that the procedure in harvesting and hauling such great masses of plant material to a central plant for the recovery of such a comparatively small amount of fiber and the losses almost unavoidably attendant upon the operation of the central plant upon this type of plant material in the manner in which it had to be presented to the machine was highly uneconomical. Thus it was estimated that of the fiber actually available in the field usually not more than 50 per cent of that total was recovered in the form of dried, marketable fiber.

This criticism led the new group to a considerable departure from this earlier procedure first in developing a ribbon cleaner that would clean rather crude field ribbons such as those produced by the Cary field harvester-ribboner without hauling the great mass of plant material to the central plant. This might be described as being built around a transport wheel that has a device for reversing ends of small hanks of ribbon to the cleaning process after they have made a full turn and other mechanical devices for loading automatic clamps on the wheel and the removal of the cleaned fiber after its second turn and the ribbons had been cleaned in full length. The actual fiber cleaning is carried out by six sets of opposed, high-speed cleaning wheels or "mills" thru which the bunches are drawn with the turning of the large master wheel, first tops (first round) and then bottoms (second round) with scraper bars on the high-speed cleaning wheels that fail to or just intermesh, depending on the intended action and the position in the series. The six sets of opposed cleaning wheels are separately powered and driven at speeds predetermined as optimum as is also the amount of water added to each "mill" during the cleaning process. The action on the fiber is, of course, graded from mill to mill. While the Pierce system of ribbon cleaning has been used on a sizeable quantity of fiber, detailed data as to cost is not yet available because the work has been limited to the first experimental machine and does not necessarily reflect the improvements in a new unit that will be in service in 1959. There is no question but that this procedure produces a beautifully clean ribbon. However, the loss of fiber from the butt or ground end of the ribbons when swept at such a distance from the holding mechanism is necessarily quite heavy and the unit cost of the operation per pound or ton of cleaned

fiber will necessarily remain high until it is reduced by greatly increased capacity and/or a high degree of mechanization to cut down on the amount of hand labor required for the operation of an individual machine.

In an effort to obtain a more even butting of the ribbons produced Pierce Florida Ramie, Inc. also has developed a field ribboner that emphasizes this point without too much, if any, regard to cleanliness thru shive removal. Consequently most of the crushed "ribbons" still retain much of the woody stem, a fact that will add substantially to the cost of handling per se as well as shive disposal in anything approaching a commercial operation.

By way of brief review of what already has been done in this phase of ramie harvesting and processing it should be mentioned that quite satisfactory results in fiber preparation have been obtained with the oven-dried ribbons from the Cary field-harvester by passing them thru an ordinary jute softener while they are still dry enough to loosen and throw out the shive and most of the bark but not do damage to the ribbon. After burnishing these ribbons that have been so treated mechanically they have been stapled and degummed in a satisfactory manner at least in 3″ to 5″ staple for the woolen and worsted systems. The operation of the Cary field harvester-ribboner along with numerous others was reviewed, with diagrammatic sketches, in Proceedings Vol. XIV, 1954.

As a matter of fact, we have felt for some time that if accurate stapling of decorticated ramie ribbons is desired in short length from the product of the Corona this best could be accomplished by removing the fiber from the rope before passing thru the squeeze rolls and stapling wet. The squeeze rolls mat and tangle the fiber mass very badly even making expensive over-drying necessary to dry out felted masses adequately so as to avoid molding in the bale. Once the wet fiber is stapled to required length it could be squeezed, centrifuged or handled in any manner, for instance mechanically, to the dryer after picking, with great reduction of cost in the whole process, both handling and drying. In other words, once it is stapled there need be no fear of tangling, at least at worsted lengths or shorter. Insofar as the ribbons that were produced by the Corona are concerned, their straightness and readiness for wet stapling are well shown in Figure 1 as they are leaving the second wheel of the machine and about to enter the squeeze rolls.

It should be noted that fully cleaned ramie ribbons have been prepared by several machines, including, of course, the standard Krupp-Corona. Mr. Frederick Mertz, formerly of the Krupp organization, recognized during World War II that an angled or gradient system of fiber cleaning for ramie might prove successful. Accordingly he designed the Krupp-Victor decorticator with an angled drum application but it proved too late for effective use in ramie supply for that war. This basic design was applied in the construction of the "Siland" decorticator by Sea Island Mills, Inc. and more recently in the work of Mr. Karl Kaiser (USDA) in Cuba, who is working on a large machine as well as a small machine. It is being used still more recently by the North Atlantic Kenaf Corporation in a unit which it has in process of building and testing particularly for kenaf in West Palm

Figure 1.—Decorticated ramie fiber leaving the second wheel of the Krupp-Corona unit on the carrier rope and about to enter the squeeze rolls further to the left. Photo by courtesy Newport Industries, Inc., (1956), Pensacola and Canal Point.

Beach. This machine, to date, looks very promising in trials with this crop.

In all fairness to any and all of these units, we are still much interested in seeing more adequate tests on ramie made with what was referred to in the earlier report as a twin-drum ribboner. Most of the early development work on this unit has been done by Mr. Mills H. Byrom and his group at the Everglades Experiment Station as well as by the Cary Iron Works over at Opalousas, La. The North Atlantic Kenaf Corporation of Havana now has four of these machines in Florida, three by purchase and a fourth by original construction, from the first three of which considerably more than 100,000 pounds of ramie fiber have been shipped to manufacturers abroad apparently with complete satisfaction to the buyers. Particularly have we seen the newest of the four units, referred to as "No. 4," deliver ribbons from seven foot stems of over-mature ramie, as well as normal ramie, of course, that were regarded as entirely satisfactory for immediate stapling in the wet. The advantages of such a harvesting and first processing arrangement are immediately apparent.

One of the most interesting and efficient ribboning principles that has been developed is that of the late Charles R. Short of Clermont, Florida, who worked privately for several years on the ribboning and degumming of ramie and other bast fiber plants, and made many important contributions. His approach uses what has been referred to

somewhat facetiously as the "nibbling" principle which reduces the stem particles to not over ½″ to ¾″ as they are broken out. Other designers have used one of Mr. Short's simple basic findings, namely that the breast plate for a decorticating wheel must be below its center line and the top inner edge of the breast plate must be a recessed secondary curved surface.

This ribboning machine, formerly called the "Baproma" and now known on the international market as the "Plantec," is still hand-fed. However, it offers very real possibilities for mechanical feeding. It is a high speed unit that ribbons rapidly without loss of fiber. Since it does not produce a completely clean ribbon a ribbon cleaner for this purpose has been designed and is under trial. This ribboner also was discussed in brief detail in the earlier report already referred to. As in the instance of the Cary field ribboner the ribbons from the Plantec doubtless could also be cleaned quite satisfactorily by passing thru a jute softener, under proper conditions of humidity, with subsequent brushing.

Inasmuch as the first efforts at developing a place for ramie in our domestic market took it directly to the cotton system with its 1½″ to 2½″ staple limit, the difficulties involved in stapling this fiber to a satisfactory tolerance in these short lengths soon became apparent. Briefly, it has been found that stapling for accuracy shall have to be in the wet while the fibers are in good alignment and before drying has produced many kinks and allowed cross fibers and even loops to develop. Mr. William Pierce and his associates in Belle Glade have so changed a standard stapling machine (Little Giant) that the feed belt advances in exact cycles of travel in such a way that it and the fiber it carries are at rest when the cutting action takes place. This, of course, greatly decreases the actual capacity of the machine. These modifications include a short hold-down belt traveling forward at the same speed as the lower one in order to keep the fiber in place as it is presented to the knife.

According to careful stapling tests that have been made on two unmodified stapling units of the same type in different locations having a continuous forward movement of the feed belt, fiber arrays even at 1½″ stapling have been obtained that were pronounced satisfactory by a laboratory that was quite demanding on this point. Although wet fiber masses may be more or less resistant to true shear cutting because of their freedom to shift between the cutting knife and the shear plate, it is believed that uniformity of feeding and over-all care in the operation, including the use of a hold-down belt of some type will make this operation possible and strong favor still will be found for it in wet stapling.

Once ramie ribbons have been satisfactorily washed and dried, following stapling where necessary, they are ready for degumming. Bleaching is usually avoided until it is known that the end use requires it. Degumming in Florida has been largely with the use of caustic soda supplemented with sodium tripolyphosphate and either Victawet or Solvadine G for their wetting and detergent action with steam pressures up to 80 pounds. Here again time has brought little change as shown by quoting again from the 1897 report of Charles Richard Dodge:

"Through the researches of the late M. Fremy, member of the French Institute, it has been shown that the gums and cements holding together the filaments of ramie are essentially composed of pectose, cutose, and vasculose, while the fiber itself is composed of fibrose, cellulose, and its derivatives. The theory of degumming, therefore, is to dissolve and wash out the gums without attacking the cellulose. In order to eliminate the vasculose and cutose it is necessary to employ alkaline oleates or caustic alkalies, employed under pressure, and even bisulphates and hydrochlorates. The gums being dissolved, the epidermis is detached and can be mechanically separated from the layers of fiber by washing. The larger number of degumming processes in present use embody these general principles."

However, as reported in Proceedings Vol. XIV, 1954, the possibilities of an in-line procedure which employs an open cook at temperatures well below boiling, as well as low concentration of chemicals, has obvious possibilities as to time and cost, as well as much-lowered recovery losses according to limited tests that have been made to date on a very small unit with which it is scarcely possible to process enough fiber for the most limited mill test. As indicated in the earlier discussion as the fiber is being processed under this procedure it is being worked vigorously all the time it is in the degumming solution. Peculiarly enough and for no reason that can be given, degumming losses encountered under this system are never more than half and quite commonly less than half those encountered under the pressure system referred to above. Likewise these very preliminary tests with this method have indicated that degumming of undried fiber may be accomplished without loss of strength whereas the same test under pressure degumming commonly shows a loss of about 25 per cent. The chief disadvantage of this method is the need for absolutely clean ribbons. For while 4 or 5 minutes are required for actual degumming, such circumstances of treatment can not be expected to eliminate bark particles especially where they are too well imbedded in the fiber blanket to be removed by simple flotation. On the whole the method is deserving of much further study with equipment having sufficient capacity to produce at least small mill samples for full evaluation and practical testing.

It is believed that one of the most particular problems remaining for solution in the preparation of ramie fiber for spinning is the development of a softening process that will give a much higher degree of loftiness in the fiber and a much better "hand" than has yet been attained. This is particularly from the standpoint of its behavior during the drafting and spinning process once the fiber is degummed and fully prepared to receive such treatment. There is a cooperative study under way at the present time with the Regional Laboratory of the U. S. Department of Agriculture in New Orleans and the Georgia Institute of Technology in Atlanta in which this problem is receiving particular attention. Many compounds have been tested and some good leads have been obtained but it has become obvious that much work remains to be done in this field of fiber preparation.

Progress Report on the Acceptance of Ramie by U. S. Industry

H. G. MORTON* and R. V. ALLISON*

If we may again refer to the 1897 fiber plant report cited in the immediately previous paper (Charles Richard Dodge—A Descriptive Catalog of Useful Plants of the World—U. S. Dept. of Agriculture, Report No. 9, Fiber Investigations) to see what the status of ramie manufacture was nearly 60 years ago we will again be a bit surprised. As of that date Mr. Dodge had the following to say regarding the industrialization of the fiber:

> "MANUFACTURE.—It is not important to go into the details of manufacture here. This branch of the industry has passed the stage of experiment and is an established fact. At the present time there are two filatures or spinning mills in France, two in Germany, one in Austria, one in Switzerland, and two English companies, one of which—the Boyle Fiber Syndicate—operates at Long Eaton. Probably the most successful spinning mills are those operated at Emmendingen, Baden, Germany."

Most, if not all, of the work with ramie that is referred to in this report was done and much of the foreign spinning with this fiber is still being done on the linen or silk system with long, unstapled fibers that have been combed out and made available for the purpose by a system of handling that the fiber can scarcely afford under our high cost conditions except the material be prepared for a special purpose that will absorb this cost. Consequently, in undertaking to adapt the fiber first of all to the cotton system—even the so-called American system—which is the lowest cost spinning system in the world, a whole litter of new problems appeared. The first of these was, of course, accuracy in the staple length, particularly in the shorter lengths demanded by the cotton system. As already discussed, the problem of accuracy in stapling largely has been resolved by performing the operation on wet ribbons. Under this condition their contained fibers can be presented in a much more satisfactory condition of alignment for this purpose than when dry.

Early in our studies of the American system of spinning the first problem encountered was found in its carding and drawing. This was studied quite intensively at Dan River Mills thru the courtesy of its very cooperative management with ramie stapled at 1½" to 2½" after it had been degummed and softened. Here, in an extensive research department, which is really the first mill of the present company that has been completely converted to this purpose, were six complete experimental cards each with different arrangements and

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*Formerly Industrial Consultant, Board of Trustees, Florida Internal Improvement Fund, and Fiber Technologist, respectively, Everglades Experiment Station, Belle Glade.

capabilities under proper adjustment for handling different fibers, including synthetics. The research division at this mill also has 48 experimental looms and other equipment in proportion, including a full floor of the building that is devoted exclusively to chemical research, all for the development of a remarkably well-integrated research program.

DAN RIVER TESTS

Following receipt at this mill of two mill samples of ramie in 2½" and 3" staple the first study was, of course, to determine if the fiber could be carded into a satisfactory sliver. For this purpose three of the experimental cards referred to above were tried in succession. The first was the one regularly used on cotton. The licker-in roll has 8 teeth to the inch, each tooth slightly curved. Trials proved that this was not the proper form of tooth since it seemed to hold the fiber too long. In this particular card, furthermore, the flats on top were set at 12/1000 inch clearance. During operation it was found that large amounts of very short fibers or "fly" accumulated at the delivery end of the card indicating that somewhere along the line there was severe tearing and breaking of the material. It was doubtless due in good part to the close clearance at which the flats were set on top of the unit.

The second card tried had just been overhauled and the teeth ground. Without going into details of its mechanical makeup it will only be reported that it did not work any better than the first one on the ramie samples.

The third card was equipped for synthetic staple fiber. The licker-in roll had twelve teeth to the inch. They were of a slender V shape and did not catch and hold the fiber as did the slightly hooked pins of the first one that was tried. The press roll on the lap in front of the licker-in roll also had 12 straight teeth to the inch. It is believed that the teeth on this press roll tend to hold back the fiber and permit the licker-in roll to function more effectively. Furthermore, the flats on this unit were set at 40/1000 clearance or more than three times that of the first unit tried. This card delivered an excellent, all-ramie sliver with very little fly or short fibers at the delivery end of the unit. This sliver weighed about 55 grams per yard.

DRAFTING—The drafting operation that followed was on an 8-sliver unit known as 3 rolls over 4. Eight slivers were drawn into one of about the same weight as the original, namely, 55 grams per yard. When it was observed that some of the short fibers were sticking on the rolls this was very quickly corrected by a light dusting with French chalk or talc. It is possible that the softener used on the fiber might have caused this tendency to stick on the rolls.

ROVING—This was the J-3-3 drafting operation. On the short staple these rolls were set on centers, top to center roll 2½" and center to front roll 2⅞". For the ramie fiber in 3-inch staple these were reset to 2¾ and 3½". This made a smooth and entirely satisfactory roving yarn.

The 1½" staple that was sent to the mill first had been spun prior

to the arrival of the writer at the plant. The yarn, a 9/1 cotton count, is smooth and satisfactory in every respect. A small sample of this all-ramie yarn, probably the first of its kind that ever has been spun on the cotton system, is here available for the inspection of any who may be interested.

It is the opinion of the research group that supervised the processing of these fiber samples that the special licker-in roll, the press roll with teeth, and the wider clearance of the flats made it possible to card this material with complete success on a cotton card. Incidentally, these special licker-in rolls are made by Ashworth Bros., Charlotte, N. C.

WHITIN TESTS

A second important spinning test on all-ramie yarn with 3" and 4" staple was conducted at the Paul Whitin Mfg. Company, Gilbertville, Mass. This fiber had been degummed by the pressure method and softened with Nopco 73. Whitin equipment was used throughout under what is coming to be known as the American system on which any fiber can be spun at staple lengths varying from 1 to 9 inches. Because of its importance to the immediate future of spinning all-ramie industrial yarns of 8/1, 6/1 and 4/1 sizes, the equipment and procedures used in this complete test will be included in brief detail. The 4" staple was placed in process first by passing it thru the Whitin N-5 after applying water as a very fine spray to the extent of 8-10 per cent on the dry fiber basis.

CARDING—The unit used for this purpose is a rebuilt, worsted card with 3 workers, 3 stripper rolls on top with an Abington roll as a doffer. A "fancy" was added to clear the main cylinder and prevent loading. Two 60-grain slivers were taken off. To prevent compressing on the sliver the hole in the trumpet on the coiler was enlarged to ⅜" and very light pressure maintained on the coiler rolls. The result was a well-formed card sliver delivered at the rate of 30-40 pounds per hour.

DRAWING—The Whitin Even Drafter with 4 over 5 rolls was used running at a speed of 300 feet per minute. To give a full, free drawing sliver the trumpet was removed and it drafted very well at full speed on both the first and second pass. The sliver was rather open, however, so it did not have good strength when taken out of the cans in roving. A special size trumpet should be developed to give just the right compression on the sliver to overcome this problem.

ROVING—This operation was performed on a Whitin Quick-Set machine in ¾ type hank with a .90 turn or slightly less than 1 per inch.

SPINNING—A whitin Super-Flex unit was used for spinning. Two roving bobbins were spun in 6/1 with 10 turns per inch and 8/1 with 12 turns per inch, cotton count. Yarns of 8/1, 6/1 and 4/1 were spun later and fabrics will be woven from them for testing as to adaptability for certain industrial purposes.

TESTING—When 120-yard skeins were used it went beyond the recording table of the Scott Tester so all breaks were made on 60-yard skeins instead. The results were as follows: 8/1 (av. 2 tests) 154; 6/1 (av. 2 tests) 225.

For comparison 60-yard skein breaks were made on long staple yarn from Japan and from Formosa and Switzerland with the following results:

Yarn source	*Size*	*Break* (lbs.)
Japan	9.5	243
Switzerland	6.7	234
Formosa	7.6	190

60-yard skeins of 8/1 and 17/2 nylon also were tested. There was so much stretch in these materials that they would not break on the full distance allowed on the Scott Tester.

At the conclusion of these tests Mr. Adams, General Manager of the company remarked, "the small problems in processing this fiber on a production basis can be resolved and we now feel we can spin it in large volume." The Whitin equipment worked in an excellent manner and all officials and employees cooperated in the work in a splendid way throughout the test. It was indeed a pleasure to work with them.

According to the spinning tests reported above there would seem to be little question of spinning all-ramie yarns with comparatively short staple if the proper equipment is used and particularly if it is given sympathetic testing thru a preliminary testing period of operation.

This brings us to the consideration of blending ramie with such synthetics as dacron and a brief review of advantage from the standpoint of both fibers. This, at least, puts us in a field of opportunity for ramie that was completely unknown and unanticipated by those reporting on the virtues and uses of the fiber sixty years ago. Just to show how closely their use listings were to those of the present which we have been talking about more recently we quote from that report again, page 90: "USES OF THE FIBER."

"As to the possibilities of ramie manufacture there seems to be no limit. Stuff goods for men's wear, upholstery, curtains, laces and embroideries, plushes and velvets, stockings, underclothing, table damask, napkins, handkerchiefs, shirting, sheetings, sail duck, carpets, cordage, fishing nets, and yarns and threads for various uses not enumerated, bank-note paper, etc. Regarding these various uses of ramie fiber in manufacture, however, M. Roux says we should not conclude that this textile is destined to be employed so largely. The cost of its preparation will always prevent its common use as a substitute for the textiles that can be more cheaply grown and prepared. He concludes that while it has brilliancy it has not the elasticity of wool and silk, nor the flexibility of cotton; but it will always be preferred for making articles requiring the strength to resist the wear and tear of washing or exposure to weather. This facility to imitate all other textiles is one of the

principal causes which has kept back the development of the ramie industry; and if, instead of launching out into a series of experiments, attention had been concentrated upon the exclusive manufacture of those articles to which the properties of the plant were peculiarly and naturally adapted, this industry would probably be in a more advanced condition than it is at present. The Department of Agriculture has held to this position since its work in this field was begun. The folly of building up a ramie manufacturing industry on a false basis, that is, employing the textile as a substitute for something else, is to be deprecated. The fiber should be used in those articles of economic necessity which would appear on the market as ramie, that any distinctive merit the textile may possess will become known, not only to the ramie trade, but to the consumers of the product."

In reference to blendings with dacron and other synthetics we would emphasize, of course, the prospective value of this fiber in blends with wool and also with certain synthetics for use in the manufacture of such products as tufted carpet yarns and packing for journal boxes and as blends with dacron for the production of crease-resistant fabrics that are much more comfortable to wear. Its use in pure form for service towels, plastic wood, weather resistant canvases, laminated products, etc. should not be overlooked.

Most of the above ideas and arguments regarding the usefulness of ramie have been rediscovered and repeated so many times since the date of this early report that they have arrived at a point of almost threadbareness. However, as inferred immediately above, the tremendous development of synthetic fibers during the past few years has doubtless created a uniquely new field for it even in the area of some of the lighter fabrics such as are used for nurses' uniforms, etc. The argument for such a fiber combination or blending runs something like this, as for instance in the case of dacron. This fiber, available in almost any denier or staple length, can be worked into a dress, suiting or shirt fabric which, while amazingly crease resistant and alluringly "drip-dry," on account of its crease resistant qualities* is just about as uncomfortable to wear, except perhaps over a very narrow range of humidity and temperature, as it is beautiful to look at. On the other hand, ramie fiber has equal or even greater tensile strength than dacron, is highly resistant to abrasion and mildew, but most importantly of all in this connection it is highly absorbent. Thus it is anticipated that a combination of dacron and ramie in a proportion of about 65/35 should be able to rely on the ramie to give the fabric what we have come to refer to as "breathing power" and the dacron, in turn, would supply a high degree of crease resistance.

First efforts at producing such a fabric have been in working with Dan River Mills, Inc. in developing and testing fabrics in three different weights, 4.3 oz., 7.4 oz., and a 6.0 oz. construction, the last mentioned being presently in process of finishing and testing. These

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*That the fiber just won't stay bent is well illustrated by experience with it in surgery when used for suture purposes. Here it has been found to "untie itself" from three square knots in ten days! It was on this account that tests with ramie were suggested in this use, or blends of ramie and dacron.

have all been worked with 3 denier dacron and about a 7 denier ramie with both fibers stapled at 1½". Without going into detail of constructions of all three fabrics we will present the testing data developed on the 7.4 ounce fabric (8/1 yarn in both warp and filling) at the Marine Corps Testing Laboratory, Philadelphia, where it was reported to be the strongest fabric in this weight ever tested. The test data is shown in the table on page 319.

More recently a very definite interest has developed in the use of this ramie/dacron blend for nurses' uniforms and a wide variety of other adaptations which a fabric of this type could serve, with its weight predetermined by the purpose for which it is intended. Likewise some very definite tests are under way in studying the adaptability of all-ramie yarns in 4/1, 6/1 and 8/1 sizes to lamination in a wide variety of products varying from table tops to gears. The results so far obtained are most promising, starting as they do with all-ramie spinning tests that have been referred to in brief detail first at Dan River Mills and later at the Paul Whitin Mfg. Company.

On the whole though, we realize that ramie is having a considerable struggle in finding a worthwhile place in the tremendous upsurge of production of synthetic fibers that has developed during modern times and their growing competition with natural fibers. However, we are now beginning to feel a considerable confidence that this place will definitely be found by working together with synthetic fibers as well as other natural fibers rather than competitively, at least insofar as its use for fabrics in the wearing apparel field is concerned.

There are indications, however, that suggest there may be about as few dull moments in the future as in the past in this regard. Reference is to such work with the Cyanoethylation of cotton as has been reported by Dr. Jack Compton and his co-workers at the Institute of Textile Technology, Charlottesville, Va.; also to the work of this institute on "New Textile Fibers with the Structural Elements of Natural Cellulosic Fibers" reported as early as February 1954. We had hoped that Dr. Compton could be present to say a few words regarding his process if only as background for the hope he may be willing to present his work in more detail at a future meeting of the Society.

I should like to summarize very briefly that we feel quite strongly regarding the outlook for ramie. As the result of many scores of consultations with representatives of a wide variety of industrial concerns, some of them the very largest in this country, we really have made some quite solid progress during the past few years in bringing the advantages of ramie to the attention of the public in general and to industry in particular. In other words, there is a new appreciation developing for this remarkable fiber that will go far in relieving it of the stigma its ornerous treatment in the past has brought to it and assist very greatly in finding a good and proper place for it in which it can best serve in the modern picture of fibers, yarns and fabrics, which is indeed growing in complexity from year to year. The real basis for this reconsideration and new interest is, of course, the fact that the recent improvements in the agricultural mechanization of the crop's handling has now placed the mass production of this fiber on a foundation that can be made attractive and profitable once the market demand for it appears.

LABORATORY REPORT
NAVMC DOP-65 (REV. 1-56)

MARINE CORPS MATERIALS TESTING LABORATORY
MARINE CORPS CLOTHING DEPOT
PHILADELPHIA 46, PA.

ARTICLE CLOTH, 35% Ramie-65% Dacron, Khaki, and CLOTH, 50% Wool-50% Dacron, Green

LABORATORY NO. 4339-R

DATE REPORTED 4 September 1957

SPECIFICATION Comparison

DATE

CONTRACTOR

CONTRACTOR NO.

REQUESTING SOURCE Mr. Harley G. Morton, University of Florida

MANUFACTURER (OR FINISHER)

IDENTIFICATION

DETERMINATIONS	RESULTS	SPEC. REQUIREMENTS
Sample No.	(1) Ramie & Dacron	(2) Dacron & Wool
Material -warp (%)* -filling (%)	70 Dacron-30 Ramie	46 Dacron-54 Wool
Weave	Plain	Plain
Width (in) (overall)	43-1/4	59-3/8
Wgt/sq. yd (oz)	7.4	5.3
Wgt/(56" lin.)yard (oz)	11.5	8.2
Threads/in -warp	44	50
-filling	37	48
Ply -warp	Single	2
-filling	Single	2
Breaking strength: (lbs)		
-warp	207	154
-filling	178	143
Color	Khaki	M-212
Dye	Vat	Chrome
Finish	Slightly boardy; harsher than Sample No. 2	Good
Acidity (pH)	6.5	6.4
Fastness to:		
-chlorine bleaching	Good	Good
-crocking -dry	Good	Good
-wet	Good	Good
-dry (dry) cleaning	Good	Good
-laundering	Good	Good
-light (140 hrs)	(Not completed)	Good
-perspiration -acid	Good	Good
-alkaline	Good	Good
Shrinkage in: (%)		
-sponging -warp	1.0	1.1
-filling	0.7	0.6
-laundering -warp	2.8	3.9
-filling	0.5 let out	2.5
Sizing (%)	3.3	1.9
Air permeability (cu.ft/min/sq.ft) -original	85.2	85.5
-after sponging	78.1	75.2
-after laundering	61.0	57.1
Tear strength: (lbs)		
-warp	19	16
-filling	18	11
Seam efficiency (%)	74	75
Abrasion resistance (average) (cycles)		
~~xxxxx~~ -dry	2048	1186
-wet	871	278
Resistance to burns	More resistant	Less resistant
Resistance to creasing	Less resistant	More resistant

*On dry basis.

TEST CONDUCTED BY (Chemist or Technologist) Edna Kelley, Leon Blackburn, John Gaspari

APPROVED BY (Head, Laboratory Branch) NORMAN SACHS Norman Sachs

NOTE Underlined results DO NOT conform to specification requirements

Improvement of Kenaf through Breeding and Selection[1]

F. D. Wilson and J. B. Pate[2]

INTRODUCTION

A program for the improvement of kenaf (*Hibiscus cannabinus* L.) was begun in 1951 because of the possible need for a suitable jute substitute. Kenaf is generally well adapted to environmental conditions in southern Florida, but several serious disease problems and the lack of suitable harvesting machinery have limited its usefulness.

The original objectives of the breeding program were outlined by Pate *et al.* (1951), who stated that particular attention would be paid to disease resistance, plant type, fiber yield and quality of fiber. Later objectives, developed through shifts of emphasis in the program, have been to extend the range of maturity and to utilize hybrid vigor through the development of synthetic varieties.

The purpose of the present paper is to report the progress made since 1951 and to outline future plans for kenaf improvement.

DISEASES

Colletotrichum disease of kenaf.

Perhaps the most serious disease encountered in 1951 was that caused by *Colletotrichum hibisci* Poll. Artificial inoculation of plants showed that most introductions were susceptible, but that individual plants in the highly heterozygous Salvadorian variety were resistant. Selection within the Salvadorian variety, subsequent crossing of Salvadorian with other varieties, and selection of resistant plants from these crosses have resulted in many resistant lines.

Racial differentiation in *C. hibisci* led to further work in selecting lines of kenaf resistant to more than one race of the fungus. This work is being discussed by Dr. T. E. Summers on this same program.

Disease caused by root-knot nematodes.

The susceptibility of kenaf to root-knot nematodes (*Meloidogyne* spp.) remains a serious problem. Two major approaches made towards solving this problem are as follows: (1) selection for nematode tolerance within kenaf lines and varieties; (2) incorporation of nematode resistance through interspecific hybridization.

Dr. Summers will discuss the work relating to selection for tolerance within lines and varieties of kenaf. It will perhaps suffice to

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[1] The research work on which this report is based was conducted cooperatively by the Crops Research Division and Agricultural Engineering Division, Agricultural Research Service, U. S. Department of Agriculture and the Everglades Experiment Station of the University of Florida Agricultural Experiment Station, Belle Glade, Florida.

[2] Geneticist and former Research Agronomist, respectively, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Belle Glade, Florida. Junior author now located at U. S. Cotton Field Station, Knoxville, Tennessee.

mention here that some progress apparently has been made (Summers *et al.*, 1958).

Attempts have been made to transfer the excellent resistance to root-knot nematodes of *H. eetveldanus* (a red-foliaged ornamental) into *H. cannabinus* (Pate, *et al.*, 1958) by interspecific hybridization and subsequent backcrossing. Interspecific hybrids were successfully produced, but were almost completely sterile. Attempts at backcrossing these F_1 plants to kenaf and to *H. ettveldanus* were unsuccessful.

Treatment of the sterile F_1 plants with colchicine resulted in a restoration of fertility. Subsequent reciprocal backcrossing of progenies of colchicine-treated plants to kenaf has been successful to a limited extent. From 566 flowers pollinated in 1957, 7 plants resulted. Their hybrid nature has been confirmed by Dr. Margaret Menzel, who is carrying out cytological analyses of the parental species and hybrids.

Further attempts will be made to combine the superior fiber type of *H. cannabinus* with the nematode resistance of *H. eetveldanus* through repeated backcrossing and perhaps through irradiation to induce translocations.

PLANT TYPE

The major objectives in breeding for plant type have been to select lines with small stalks of uniform size and with resistance to lodging. Environmental factors, particularly those which influence uniformity of stand, play an important part in affecting stalk size. However, varietal differences have been observed, and superior varieties have been selected.

FIBER YIELD

Strain tests carried on for several years have shown that lines derived from the Salvadorian variety of kenaf have been superior to other lines in green yield, percent fiber and fiber yield. Also, *Colletotrichum*-resistant lines have given much higher yields than susceptible lines and the parent Salvadorian variety (Table 1).

FIBER QUALITY

Improvement in fiber quality has been made indirectly through selection for resistance to the *Colletotrichum* disease and for superior

TABLE 1.—Green Yields, Fiber Percentages (Green-Weight Basis) and Calculated Dry-Fiber Yields of Kenaf Lines and Varieties of Different Parentage (Data from Strain Tests Conducted at the Everglades Experiment Station, 1957).

Line or variety	Green yield (lbs./acre)	Percent Fiber	Fiber yield (lbs./acre)
Highest yielding *Colletotrichum*-resistant Salvadorian line	73,020	5.20	3,769
Colletotrichum-susceptible Salvadorian line	38,320	3.63	1,422
Highest yielding Javanese x Salvadorian line	61,880	4.27	2,627
Parent Salvadorian variety	42,220	4.39	1,857
Javanese line	28,360	2.96	843

plant type. Recently, attention has been given to selection of types with fine fiber. Kenaf fiber is coarser than jute fiber, on the average (E. G. Nelson, personal communication), a characteristic which may be objectionable to some manufacturers.

MATURITY

Kenaf lines and varieties of diverse parentage differ widely in their flowering response to the length of the photoperiod. Crane and Acuna (1945) found that fiber percentages increased up to the flowering stage and then remained relatively constant. Also, fiber quality decreases and extraction of fiber becomes more difficult with the onset of fruiting. Thus, the most useful lines of kenaf for fiber production in southern Florida are those which grow for a sufficiently long period to produce good-fiber stalks before flowering is initiated.

Salvadorian lines which have given the highest yields are of medium maturity. That is, they generally flower in early to mid October if planted in spring or summer. One objective of the breeding program has been to combine the superior yield characteristics of the best Salvadorian lines with those of other lines of earlier and later maturity to extend the period of harvest. Several good early- and late-maturing lines have been developed.

HYBRID VIGOR

Hybrid vigor has been observed in kenaf hybrids (Jones, *et al.*, 1955). The possibility of utilizing this vigor in synthetic varieties of kenaf has been considered during the breeding program. Diallel crosses have been made recently with the objectives of studying combining ability, vigor of the hybrids, and other characteristics of importance in kenaf. The success of this approach will be determined in part by developing methods to insure cross-fertilization of the desired parental lines on a large scale. This might be feasible through the use of a selective gametocide, such as sodium α, β-dichloroisobutyrate (Eaton, 1957) or through cytoplasmic male sterility which, unfortunately, has not been found in kenaf up to the present.

LITERATURE CITED

1. Crane, J. C. and Acuna, J. B., 1945. Growth and development of kenaf, *H cannabinus* L. with special reference to fibre content of the stem. Agron. Jour. 37: 351-359.
2. Eaton, F. M., 1957. Selective gametocide opens way to hybrid cotton. Science 126: 1174-1175.
3. Jones, M. D., Puentes, C., and Suarez, Rene., 1955. Isolation of kenaf for seed increase. Agron. Jour. 47: 256-257.
4. Pate, J. B., Joyner, J. F., Gangstad, E. O., and Seale, C. C., 1951. The breeding of improved varieties of kenaf, sansevieria and ramie for South Florida. Proc. Soil Sci. Soc. of Fla. 11: 140-141.
5. Pate, J. B., Summers, T. E., and Menzel, M. Y. 1958. Resistance of *Hibiscus eetveldianus* to root-knot nematodes and the possibilities of its use as a source of resistance in kenaf, *Hibiscus cannabinus* L. Plt. Dis. Rptr. 42: 796-797.
6. Summers, T. E., Pate, J. B., and Wilson, F. D., 1958. Extent of susceptibility within kenaf, *Hibiscus cannabinus* L., to root-knot nematodes. Plt. Dis. Rptr. 42: 591-593.

Important Diseases Affecting Kenaf in Florida[1]

T. E. Summers[2]

Kenaf, *Hibiscus cannabinus* L., is subject to a number of diseases which affect the quality of fiber as well as plant growth and fiber yield. Certain diseases may also alter growth habit and internal or external stem characteristics and even destroy the root system of the plant. When plants are thus affected the harvest operation becomes more difficult, and the fiber yield may decline sharply.

COLLETOTRICHUM DISEASE OF KENAF

The fungus *Colletotrichum hibisci* has been a serious pathogen of kenaf. It infects seedlings, the stem, leaves, apical region of the plant, and seed capsules. The fungus is seed-borne and possibly soil-borne. This disease has been referred to as anthracnose and tip-blight (1,2).

When the disease manifests itself through the destruction of the terminal growing point, lateral branching and stunting of the plant are induced. Such plants are obviously unfit for fiber production if infection occurs early in the life of the plant (Figure 1).

Selections and varieties of kenaf developed in Florida and Cuba possess satisfactory resistance to the known races of *C. hibisci* (1,3,5). A constant watch is maintained for the appearance of new or unreported races.

STEM DISEASES

Among the stem diseases of kenaf are those caused by *Macrophomina phaseoli*, *Macrophoma urenae*, *Colletotrichum hibisci*, *Phoma* sp., *Sclerotium rolfsii*, *Rhizoctonia* sp., and bacteria. Extensive stem lesions may cause stalks to break or bend and even kill the plant. The kenaf ribbons shown in Figure 2 illustrate another type of damage due to stem disease organisms. Some ribbons are broken at the lesions and a portion of the fiber lost during the ribboning process. Some organisms cause a discoloration of the fiber which may or may not be accompanied by weakening; in other cases the fiber in the lesion area completely disintegrates. It should be mentioned that much of the damaged fiber is removed during the process of cleaning the fiber and in the carding process. Work is now underway to qualitatively determine the extent of damaged fiber which ultimately does occur in the finished yarn.

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[1]Research work conducted cooperatively by the Crops Research Division and the Agricultural Engineering Research Division, Agricultural Research Service, the U. S. Department of Agriculture, and the Everglades Experiment Station, of the University of Florida Agriculture Experiment Station, Belle Glade, Fla.

[2]Plant Pathologist, Agricultural Research Service, U. S. Department of Agriculture, Belle Glade, Florida.

Figure 1.—Lateral branching of susceptible kenaf plant induced by *Colletotrichum hibisci*. Note lesions on upper portion of stem.

NEMATODE AND ROOT DISEASES

A critical problem now facing kenaf culture in Florida is caused by root-knot nematodes (*Meloidogyne incognita* and *M. incognita acrita*)[3] and root decay caused by associated fungi. The seriousness of the problem has been reported previously (6). This problem is being attacked through three coordinated approaches as follows:

1). Incorporation of resistance to *M. incognita* and *M. incognita*

[3]Appreciation is expressed to A. L. Taylor, Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland, and B. G. Chitwood, formerly State Plant Board, Gainesville, Florida, for identification of the nematode species.

acrita into *H. cannabinus* by crossing kenaf with related resistant species (4). This phase has been reported before this Society by F. D. Wilson, our plant breeder.

2). Selection of kenaf plants tolerant to *M. incognita* and *M. incognita acrita*, plants resistant or tolerant to root-decay inducing fungi, and plants which possess the capability to readily produce new roots which replace those destroyed by nematodes and/or fungi. Thus far, tolerance or 'resistance' of these types has been found only in the Salvador variety and in lines of kenaf derived from this variety (7).

3). Minimization of damage from the above-mentioned organisms by cultural practices including crop rotation, flooding of the soil, and the use of soil fumigants.

Figure 2.—Kenaf ribbons from diseased stalks; broken ribbon (right) and discolored areas and holes in the ribbons, which indicate location of stem lesions.

LITERATURE CITED

1. Crandall, B. S., and Harold D. Lynn. 1954. The resistance of kenaf varieties, hybrids, and relatives to anthracnose. Plt. Dis. Rptr. 38: 311-313.
2. Pate, J. B. 1953. Resistance in kenaf to *Colletotrichum hibisci*. Phytopath. 43: 647-648.
3. Pate, J. B., and Thomas E. Summers. 1955. Reaction of kenaf introductions and selections to races of *Colletotrichum hibisci*. Plt. Dis. Rptr. 39: 776-778.
4. Pate, J. B., T. E. Summers and M. Y. Menzel. 1958. Resistance of *Hibiscus eetveldianus* to root-knot nematodes and the possibilities of its use as a source of resistance in kenaf, *Hibiscus cannabinus*. Plt. Dis. Rptr. 42: 796-797.
5. Summers, T. E., Physiologic specialization of *Colletotrichum hibisci* Poll. on kenaf. 1954. Plt. Dis. Rptr. 38: 483-486.
6. Summers, T. E., and C. C. Seale. 1958. Root-knot nematodes, a serious problem of kenaf in Florida. Plt. Dis. Reptr. 42: 792-795.
7. Summers, T. E., J. B. Pate, and F. D. Wilson. 1958. Extent of susceptibility within kenaf, *Hibiscus cannabinus* L., to root-knot nematodes. 1958. Plt. Dis. Rptr. 42: 791-793.

Jute Improvement in Taiwan[1]

H. S. CHANG[2]

Jute (*Corchorus capsularis* L.) belongs to the basswood family or Tiliaceae, and is the most important fiber crop in Taiwan. It is used mainly for weaving into gunny bags to pack the 800,000 metric tons of sugar and 1,850,000 metric tons of rice produced annually, and also for making twines for farm use. The annual consumption of retted jute amounts to 18,000,000 kilograms. In the year of Taiwan's restoration (1946), the acreage dropped to 2,500 hectares, from a value of 25,000 hectares in 1939. Production of retted jute in 1946 was 1,200,000 kilograms, about one-eighth of the production in 1939. Since then, efforts have been made to increase production in order to meet local demands and to reduce imports of gunny bags. In view of the limited land area, production of jute for export does not seem very logical. The jute program of Taiwan is therefore limited to a supply of enough retted jute to meet domestic needs. The acreage yield and production of jute from 1947 to 1957 are listed below (Table 1).

TABLE 1.—JUTE ACREAGE IN HECTARES, YIELD AND PRODUCTION OF RETTED JUTE, TAIWAN, 1947-1957.

Year	Acreage (hectares)	Retted Jute: Unit Yield (kilograms/hectare)	Retted Jute: Production (kilograms)
1947	3,778	685	2,587,600
1948	16,600	685	11,366,300
1949	11,094	797	8,839,800
1950	9,152	766	7,009,300
1951	12,174	890	10,840,600
1952	16,229	1,241	20,144,519
1953	6,791	787	5,342,570
1954	11,230	1,140	12,804,722
1955	14,960	1,252	18,729,239
1956	13,562	1,277	17,323,275
1957	6,755	1,340	9,052,741

It may be seen from the data in Table 1 that the acreage of jute fluctuated widely from year to year. With the exception of 1952, when more fiber was produced than needed, production of jute has been insufficient for domestic demand. This is mainly accounted for by the price of retted jute relative to prices of competing crops. The practice of announcing jute prices before the planting season gives the farmer an opportunity to make a choice as to whether or not he

[1]This manuscript was received by Vice President Senn in St. Petersburg on the morning of the first day of the meetings. It was presented in abstract form in the course of the program by Dr. F. D. Wilson who also very kindly assisted with the editing of it in preparation for publication in this Proceedings.—Ed.

[2]Specialist, Plant Industry Division, Chinese-American Joint Commission on Rural Reconstruction, 25 Nan Hai Road, Teipei, Taiwan.

will plant jute. Thus, it is evident that economic considerations (except in 1957; see below), rather than natural conditions, have been the main limiting factors in jute production. The general trend of increase in unit yields (kilograms per hectare, Table 1) is significant in this respect.

In the last decade, varietal and cultural improvements have been made, physical facilities strengthened, and grading and inspection systems established through government sponsored programs. These may be briefly cited as follows:

1. Varietal improvement of jute:

a. Between 1948 and 1950, the Taiwan Agricultural Research Institute made selections on a limited scale from existing varieties and conducted regional tests in six localities. As a result, the varieties "Huwei Green Bark No. 7," "Hsinfeng Green Bark," "Taichung Special No. 1" and "Shuishang Green Bark" were selected as more desirable in their respective areas. Since 1952, extensive selections of plant material from the fields of 1,000 farmers in the major jute producing area were made by the Tainan Cotton and Jute Experiment Station with the assistance of the Joint Commission on Rural Reconstruction (JCRR). A total of 11,037 individual jute plants were selected from over 300 villages in 83 townships located in 13 prefectures, or municipalities from Taoyuan to Pingtung. With this primary selection from such a wide area, a solid foundation has been laid for jute selection work in Taiwan. Through successive steps of selection and breeding, nine new strains were obtained in the first preliminary yield test. These promising strains were then tested further. In 1958, the best strain, Y-6-466, together with three promising strains selected from other sources, are being put together in a regional trial conducted at nine locations.

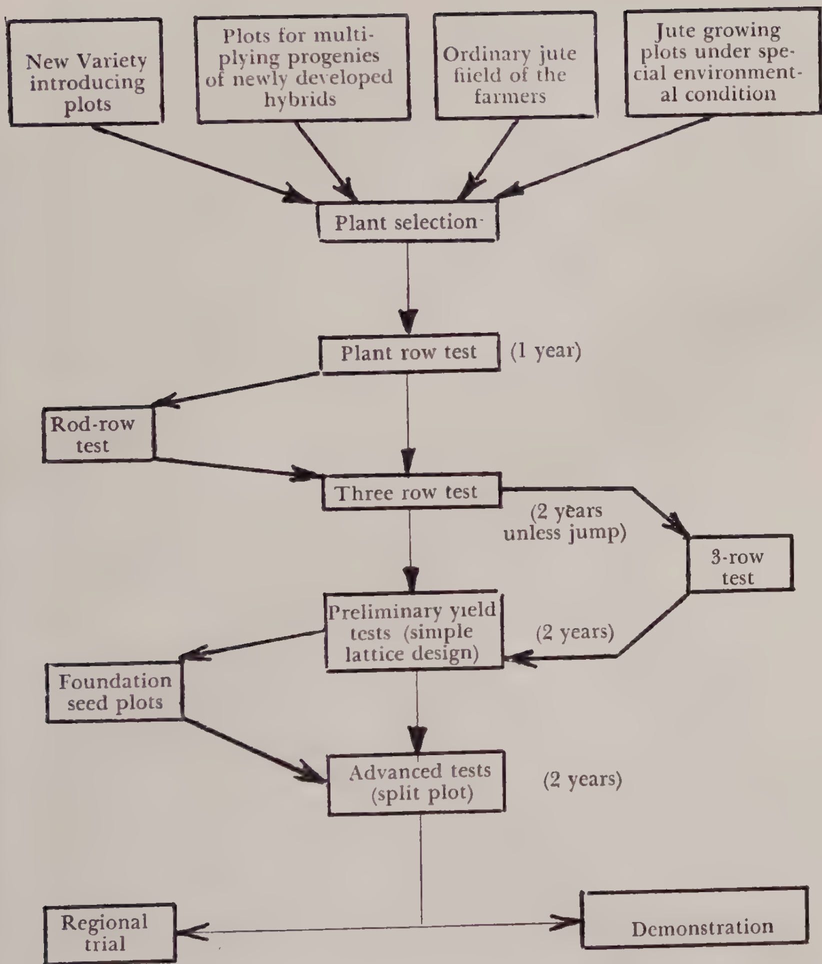
b. Hybridization between existing varieties and of Halmaheira No. 5 with existing varieties has been carried out in order to combine high yielding capacity with disease resistance. This program is still in progress.

c. Prior to 1952, no standard procedure in the jute breeding program was followed, and the method used varied with different plant breeders. From 1952 to 1953, through repeated discussions and revisions, a standard procedure for jute breeding was established and put into effect. This procedure is outlined in the following diagram:

2. Cultural improvements.

The steady increase of unit yield of jute in the past ten years is due mainly to improved cultural practices. The use of Spergon (1:100) to prevent damping off disease, liberal application of compost in addition to chemical fertilizers, frequent weeding and cultivation, and proper methods of retting are all aimed at increased yields and improved quality. Studies on seed collection and multiplication in winter months show signs of hope toward eliminating seed shortages caused by typhoon damage.

Ordinarily, jute is sown in April and harvested in August for fiber. The plants are cut by hand, after which the bast layer is stripped from the stem. The bast layer, after being dried in the sun, is called crude



jute. Sometimes the tissues are scratched from the ribbons with knives, then dried to give a product called scratched jute. Retting of green ribbons is accomplished in 10-14 days by immersion in water.

For seed collection, farmers usually keep a few rows of plants for 50-60 days after harvesting for fiber. Unfortunately, the threat of seed damage or destruction by typhoons is ever-present. This happened in 1956 when three typhoons swept over the Island in the fall season. Seed production was badly affected and shortages resulted the following year. The significant reduction of the jute acreage in 1957 was chiefly due to this reason.

Experiments conducted since 1956 have revealed that seeds collected from the fall crop (November) can be sown in December in southern Taiwan where winter temperatures are comparatively mild. The crop will produce mature seeds in sufficient time (April) for fiber plantings. If further tests confirm these results, the problem

of seed shortages caused by typhoons will no longer be of importance.

Experiments on transplanting of jute have helped to solve the problem of overcrowded planting schedules on the same piece of land. Jute seeds can be sown in the seedbed and later transplanted in rows in the paddy field two weeks before harvest of the first rice crop. Then in early August, when the jute crop is harvested, the second rice crop can be planted. This transplanting method also eliminates the problem of drought that occurs during the sowing season. The rainy season in the principal jute producing area normally lasts from April to October. However, the rainy season may arrive 20-30 days late, which makes it difficult to plant jute in time. By adopting the transplanting method, jute seedlings may be raised in the nursery where irrigation water is available. Seedlings may be transplanted into the field as soon as the rainy season commences. Transplanted jute has been found to yield as well as jute treated normally.

3. Strengthening of Physical Facilities.

In the course of jute production and marketing, some basic equipment is indispensable. A retting pond is required for jute retting, a process necessary for producing fine retted jute from crude ribbons. Then, in jute purchasing centers, screw type baling machines (manually operated) are used to pack dried jute fibers into 100 kilogram bales. Before shipping to the jute mill for manufacturing into gunny bags, the bales of jute are stored in warehouses temporarily.

After World War II, much of the needed equipment was damaged. From 1950 to 1951, with the assistance of JCRR, 332 cement retting ponds, drying racks (total 8,694 meters long), 60 baling machines, and warehouses (total capacity: 5,206 square meters) were installed in the jute producing centers. In addition, JCRR gave technical and financial assistance to the Tainan Cotton and Jute Experiment Station of TARI in breeding work, in experiments on improved cultural practices, and in providing equipment for their successful implementation. This assistance has greatly facilitated the processing, handling and marketing as well as research work on jute production in Taiwan.

4. The Establishment of Jute Grading and Inspection Systems in Taiwan.

The system of production and marketing of jute in Taiwan requires careful planning and coordination between all parties concerned. The current policy of the Government of Taiwan is to encourage production of an adequate supply of jute for domestic consumption. The projected goal, including both production and acreage, will be set, and prices of jute to be produced in the coming year will be announced at a time well in advance of the planting season. Farmers, after having decided to plant jute, must enter into a contract with the Farmer's Association in order to be eligible for the privileges offered them. Usually, they obtain production loans without paying interest. They also receive technical supervision and advice from Township workers. After the crop is harvested, the retted fiber will be purchased by the designated agency according to the pre-

TABLE 2.—RETTED JUTE

Grade / Particulars	First	Second	Third	Fourth	Fifth
Length	Over 1.82 m.	Over 1.52 m.	Over 1.21 m.	Over 0.97 m.	Over 0.76 m.
Fiber quality	Fibers excellently loosened, very fine	Fibers excellently loosened, very fine	Fibers well loosened, ordinary fine	Fibers loosened, not very fine	Fibers loosened, coarse
Color	Silvery white	Silvery white	Silvery white or white	Greenish or dark	Greenish or dark
Luster	Very bright	Bright	Ordinary	Slightly dull	Dull
Texture	Very soft	Soft	Ordinary	Slightly hard	Hard
Degree of Retting	Excellent no mixture	Good, no mixture	Ordinary, no other mixture	Retting less desirable, mixture not over 2%	Retting undesirable, mixture not over 13%
Strength	Very strong	Strong	Ordinary	Slightly weak	Weak
Drying	Excellent	Good	Fair	Fair	Fair

TABLE 3.—CRUDE AND SCRATCHED JUTE

Grade / Particulars	First	Second	Third	Fourth
Length	Over 1.95 m.	Over 1.67 m.	Over 1.36 m.	Over 1.06 m.
Texture	Very soft	Soft	Ordinary	Inferior
Color	Bright red or bright green or bright loquat color	Red, green or loquat color	Red, green or loquat color	Slight dull
Luster	Very bright	Bright	Ordinary	Inferior
Degree of processing	Completely of bast layer, no other mixture	Completely of bast layer, no other mixture	Mixture not more than 1%	Mixture not more than 1%

announced prices. Production loans will be deducted from the proceeds of fiber produced by the farmers. The purchased fiber will then be allocated to the four jute mills for the manufacture of gunny bags.

Grades and standards for retted jute, (Table 2), crude jute and scratched jute (Table 3), were established in 1949, in order to set fair prices for upper and lower grades of jute, to encourage farmers to produce better grades of fiber, and to eliminate the possibility of disputes during purchasing. These grades and standards are being modified from time to time according to weather conditions, growth condition of the crop, etc., and are being followed by both the farmers and the purchasing agency. Jute samples of different grades are collected from each crop and sent to the purchasing centers as reference standards for the inspectors.

5. Conclusion.

The jute policy of the Government of Taiwan is solely to encourage production of enough raw material for manufacturing gunny bags to meet local demands. In the past ten years, although the stage of self-sufficiency has not been fully reached, imports of gunny bags and retted jute have been greatly reduced. In view of the steady increase of its unit yield, an acreage goal of jute in each year between 15,000 and 16,000 hectares, possibly giving a total production figure of 20,000-30,000 metric tons of retted jute, would be enough to meet the yearly consumption needs in Taiwan. Jute produced in Taiwan and made into shipping bags for Taiwan sugar and rice have been favorably accepted by the recipient nations. This indicates that the quality of jute bags produced in Taiwan is up to the standard for the world market. The Government has adjusted jute prices to a reasonably high level this year (1958) so that it can compete with other crops (i.e., peanuts, sweet potatoes). It is therefore predicted that jute production in Taiwan will reach a fairly stabilized condition in the not too distant future.

PROGRESS REPORT ON THE DEVELOPMENT OF A SATISFACTORY FIELD HARVESTER-RIBBONER FOR KENAF

A) In Cuba —

JOSEPH F. DRYER[1]

I am very pleased to be here this afternoon to help represent the Kenaf Growers of Cuba, and to talk with you briefly about our experience and the problems encountered in growing Kenaf during the last eight years, and to tell you something of the Kenaf fiber harvesting machinery that we have found it necessary to develop in order to economically produce and process this crop.

When our Company, the North Atlantic Kenaf Corporation first started growing Kenaf in 1951 in Florida and Cuba, we were faced with either hand harvesting, or harvesting by the only available machine, the ancient war hemp binders. The stalks, either cut by hand and loaded into carts, or cut and bundled by the binders, presented a problem of handling. The weight and bulkiness of full grown Kenaf, with leaves and moisture, is very great, and in Cuba, where the cost of our field labor is considerably higher than other areas of Latin America, Africa, and especially Indian and Pakistan, we were faced with a very serious problem of competition.

Let me say at this time, that our experience in hand harvesting using a hand-fed ribboner, required an absolute minimum of at least 15 men to cut the stalks, bundle them, feed the ribboner, collect the ribbons, and carry the ribbons to a drying yard where they were sun-dried. Actually, we preferred to use 20 men to keep up production. Although we could have used fewer men, we needed the full 15 men in order to keep the ribboner working at full capacity. The principal problem that we found in the hand-fed ribboner was the inability of 3 men to feed the machine faster. The average production that we achieved per hour was 150 lbs. of dried ribbons. A higher production per hour can be achieved, but in the hot sun hour after hour we found that the average production was 150 lbs. and that the relatively narrow feeding tables could not be fed faster by human hands.

In terms of cost, this meant that 20 men and a $3,000 ribboner were producing about $10.00 worth of dried ribbons per hour (valuing the ribbons at 7¢ per lb. in 1953 and 1954).

Using a labor cost of 25¢ per hour and a fuel cost for diesel fuel of 20¢ per gallon our total harvesting cost averaged close to 4.05 per hour. A total of 20 hours was needed to harvest 1 acre or roughly 50 hours per hectare. This brought our harvesting cost to almost $81.00 per acre or 2.7¢ per pound of ribbon.

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[1]President, North Atlantic Kenaf Corporation, Radiocentro 513-514, Havana, Cuba

This experience was so discouraging to us, that in 1953 we set about designing a self-propelled harvesting machine that would cut, ribbon, and clean the fiber in one operation.

The availability of a self-propelled harvesting machine for bast fibers we believed would open up almost all of the Latin American, Southern United States, European, and African countries to a more rapid development of Kenaf, especially the areas with large growers. Each country that lies between 35° North and South Latitude could become self sufficient for most of its bagging requirements. Those countries with a surplus of good land and good rainfall could also become exporters of baled Kenaf fiber and Kenaf fiber products.

Our Mobile Kenaf Ribboner operating on our farm near Havana is the culmination of five long (and expensive) years of work aimed at achieving this goal. It produces kenaf ribbons at a very low cost per pound. These ribbons can economically be spun into the heavy duty sacking required by the booming coffee, cacao, and grain industries of Latin America and Africa. The harvesting machine is a fully operative model. Reductions in size, weight, and cost can be made in future models. This machine will produce 1,000 lbs. of dried ribbons per working hour, at an out of pocket cost delivered to a cart in the field (not including depreciation) of $2.00 per hour in Cuba or $6.00 per acre.

These same ribbons can be spun and woven into bags of the same quality and strength as the magnificent coffee bags spun by Mr. Wenneal Dalton of Salvador in his Kenaf Bag Mill.

I would like to say that Mr. Dalton's Bag Factory and his production of several hundred thousand coffee bags is indeed an inspiration to us all. Mr. Dalton deserves great credit for his persistence and ingenuity in establishing the world's first purely Kenaf Bag Mill. Although the dried Kenaf ribbons are nowhere near as fine a fiber as retted jute, I think that their low cost of production, combined with the splendid acceptance of Mr. Dalton's bags by the Coffee Trade tell their own story. Mr. Dalton has successfully placed a mill in operation using dried ribbons, he has sold his bags and we understand the trade wants to buy every single one that he has for sale. This is our best proof that the Kenaf industry is successfully launched.

Realizing that a harvester-decorticator would be of even greater economic value to the industry than a harvester-ribboner, the directors of NAKCORP in 1957 authorized funds for the simultaneous development of such a machine.

In the Palm Beach Area we presently have such a Mobile Harvester Decorticator undergoing field tests. This machine has exciting possibilities for already it is producing decorticated fiber, samples of which will be on display later. This machine, like the ribboner, is operated by only two men. It is ⅓ the weight of the Cuban Harvester-Ribboner, ⅓ of the size, and will cost considerably less.

The North Atlantic Kenaf Decorticator and the Harvester-Ribboner are, we believe, the most advanced designs in the field today. Although they are still in the adjustment stage, we have reason to believe that tests will be concluded at an early date and that orders can be taken in early 1959 for summer delivery.

The total operating costs of the decorticator are less than the Harvester-Ribboner while the fiber is considerably higher in value. Production of dried fiber per working hour should approximate 1,000 pounds.

As there will certainly be mills and products requiring a higher grade fiber than the dried ribbon for heavy sacking, we believe that this machine and its decorticated fiber will satisfactorily provide the answer. To name a few products, this machine should produce excellent fiber for standard sugar bags, rice sacking, plastic reinforcement material, curtains, and possibly carpet backing.

I would like to mention bacterial retting for a moment. Retting, or eventually a system of chemical extraction will of course produce the ultimate in fiber and will always be needed to produce fiber for certain quality markets, and especially in the United States. However, I don't think many people will question the fact that decorticated fiber is satisfactory for the major part of the huge sacking market that exists in Africa, Latin America, Europe, and the United States. We are also hoping that yarns from our decorticated fiber can be spun into twines for the packaging industry.

Briefly, our Harvester-Decorticator is a comparatively light-weight machine capable of operating on most types of soils. It will travel on a highway under its own power at 35 miles per hour. It is designed to work 15 hours a day. The machine cuts the stalks in the field, picks them up, lays them down laterally on moving chains that carry them through decorticating drums and delivers the fiber a few seconds later in straight form ready to be dried.

We have worked with competent recognized machine builders during our development period. We will, as a result, be in a position to quickly go into production on each machine, as soon as they are completely field tested and proven.

The Harvester Ribboner has been produced for our account by a commercial machine builder, from complete engineering drawings prepared from the successful field built prototype.

The North Atlantic now has in the blueprint stage a mobile field dryer that will be synchronized with the harvester. The dryer will be towed into the field and will receive and dry the fiber at the same rate as produced by the harvester, 1,000 lbs. per hour. We also have in the blueprint stage, solar (sun) heating units for the retting tanks that in effect will allow companies in the cooler areas, or that have cool nights, to ret all year round. We learned from our experience with controlled retting several years ago, that control of the temperature, pH and some circulation is very helpful in reducing the retting period for the production of the finest quality fibers.

It is our intention to make all of our machinery available on a reasonable cost basis to the entire industry. We do not believe it will serve the best interests of our corporation, or of the industry, to attempt to acquire an exclusive position in this respect.

It is our further intention to carry on a continuing program of engineering research on machinery development and refinement that will include harvesting equipment, mobile fiber drying machines, washing machines, and solar heating units for retting.

We are also working on new seed varieties for future release that will produce a finer quality fiber and ease the work of our mobile harvesters.

In closing, let me express to you on the part of my Company and myself that we are very pleased to have been included in this conference for it is our hope that Kenaf will now find its true and rightful place in the world of fibers. It is also our hope that this conference will give added impetus to the many countries involved in developing the Kenaf Industry. The future indeed appears bright in view of the benefits that can accrue to many national economies and their people.

B) In Florida —

Hiram D. Whittemore[1] and Robert E. Hellwig[1]

INTRODUCTION

Engineers and plant scientists of the Agricultural Research Service, USDA, in cooperation with the Florida Agricultural Experiment Station have been conducting research on kenaf for a number of years at the Everglades Experiment Station, Belle Glade, Florida. One phase of this project concerns the development of harvesting and processing equipment.

Several methods of harvesting kenaf are possible depending on what further processing is planned. One practical approach is the combining of harvesting and ribboning of the stalks into one operation. For most of the usual finishing processes, ribbons are satisfactory, and for many superior to stalks. In addition, the ribbons are more easily handled and the total weight is reduced by about 70 percent by leaving a large portion of the waste in the field.

The design of a harvester ribboner must take into consideration certain characteristics of the kenaf crop. Its tall growth, pithy brittle stems and tangled top growth are all factors that necessitate the use of heavy cumbersome machinery.

On Florida sand lands these problems are often reduced by proper seeding and early harvest. However, even with the best conditions, kenaf remains a difficult crop to harvest.

HARVESTING

Separation of the swath to be cut from the standing growth is largely the key to successful harvesting as actual cutting can be achieved with either a heavy duty reciprocating cutter bar or a rotary cutter.

Separation by divider boards such as those used on mowing machines and grain binders is inadequate and some mechanical action by either chains or belts is necessary. Careful shielding of gears, sprockets, chains and similar moving parts is required because of the tendency to choke up and become ineffective.

Once the cut stalks are separated they must be moved into position for ribboning. The United States Department of Agriculture's field harvester-ribboner gathers and holds the stalks in a vertical position while they are being cut at the base and are having the excess height and foliage removed from the top end. The stalks are then moved into a horizontal position, and conveyed to the desired position for ribboning. For economic reasons the distance should be as short as possible.

[1] Agricultural Engineers, Long Vegetable Fiber Plants Section, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, ARS, USDA.

Top gathering and conveying have certain advantages as well as undesirable effects. In fields where stalk height is fairly uniform, top gripping is satisfactory. However, trash in the form of second growth, immature stalks, weeds, etc. needs to be separated out mechanically before ribboning whenever possible. Failure to provide means to accomplish this complicates further operations.

Fields containing mature stalks of greatly varying height cannot be harvested easily by this method unless the gripping point can be sufficiently lowered to gather all standing stalks.

An alternate method for gathering the stalks is to cut them near the base and let them fall backwards into a conveying mechanism such as canvas aprons or chains, by which they are transferred to the ribboning unit. This type of cutting and gathering is suitable for fairly wide swaths. On such swaths a reel or other mechanical means is necessary to keep the stalks falling in the proper direction. Weeds, dead stalks, and immature stalks are harvested by this method and therefore they must be handled until they can be eliminated. However, very little separation is possible and most of the material longer than a few feet must go through the ribboning process where all non-fiberous matter is eliminated.

Kenaf is usually a very tall growing crop reaching 9-12 feet when mature. For this reason, it is usually advisable to harvest prior to reaching maximum height, but even then a machine designed to harvest kenaf must be capable of handling stalks of considerable length. The upper portion of the stalk contains only a small percentage of the total fiber and is usually cut off and discarded. This topping is accomplished with circular saws of various types. A peripheral speed of eight to ten thousand feet per minute is necessary to assure clean cutting.

Topping may take place at any point between cutting and ribboning. It is important that this point be one which allows the tops to fall clear of the machine and the uncut portion of the field.

RIBBONING

The twin-drum principal of ribboning was proven to have very high capacity and produces ribbons completely free of shives and wood. Operating speeds for the rotating drums should be adjusted for best cleaning and lowest loss for the type of material being ribboned.

The diameter and length of drums now in use on the USDA machine can handle stalks topped to eight or nine feet. However, if stalks with an average length of more than eight feet are to be ribboned the 36″ diameter should be increased since the ribbon will wrap its length around the drum. Drums twenty inches in length are used in the USDA ribboner.

Each drum has six blades running the length of the drum and each blade is serrated or scalloped, with high points on alternate blades thus producing a combing action. This basic design appears satisfactory but is subject to modification on new models particularly on the angle at which the stalks approach the drum. This is now accomplished by use of a cone section leading the stalks up and over

the drum while the grip chain holds the material on the approximate center line of the drums horizontal axis.

Transfer of the fiber stalks between the two drums is accomplished by use of offset grip chains. The first set of grip chains feed the lower portion of the stalk to the first drum and the stalks transfer to a second set of grip chains which carry the unribboned portion of the stalks through the second drum to complete the process.

To conserve space and save material the two sets of chains can be placed on common shafts, but more effective transfer can be accomplished by making each set on separate shafts with the second set designed to pick up the ribbons before the first set have released. This gives a more positive transfer.

Ribbons of kenaf produced from a four foot cut at a fairly good ground speed can mean a very considerable quantity of material to be handled at the discharge end of the machine. The final use to which the ribbons are to be put will influence the method of handling them. Hanking, tying in bundles, and placing on poles are some of the methods used to prepare the fiber for retting or drying.

Crushing of kenaf stalks, some time between cutting and ribboning, is desirable and necessary with large stalks. Efficient crushing reduces the fiber loss and fiber damage by lessening the mechanical action needed for good ribboning.

The kenaf stalks are crushed while in a horizontal position just ahead of the ribboning drums. This is accomplished by the use of heavy rollers supported on the feed table and mechanically rotated.

Crushing rolls can be of several types: plain metal, neoprene covered metal, corrugated metal, rope covered metal or modifications and combinations of various types. The USDA crushing rolls are made of 10 inch steel pipe equipped with flat ½ x 1" metal bands welded at intervals along the length of the rolls, the top roll having a band acting between two bands on the lower roll. This, in effect, breaks the wood into segments of six or seven inches.

SUMMARY

The United States Department of Agriculture has for several years carried on research on basic principles involved in field harvesting and ribboning long fiber plants. A tractor drawn, gasoline engine driven machine was built using a twin-drum type ribboning unit and several harvesting and gathering mechanisms mounted on tractor or ribboning unit. No attempt has been made to create a production type machine for any one crop, but rather one that could be used to test certain basic principles of harvesting and ribboning. It is hoped, however, that the principles developed and work done will provide sufficient knowledge for building prototype machines which can be readily adapted to meet any need.

REFERENCES CITED

1. Whittemore, H. D. and J. B. Cocke. 1954. Mechanization of Kenaf Fiber Production. Agricultural Engineering Vol. 35, No. 7, pp. 488-491.
2. Kenaf: A potential Cuban Industry. Stanford Research Institute Project Report. No. I-1875, August 1957.

Biological Retting of Kenaf, A Progress Report[1]

T. E. SUMMERS, J. W. RANDOLPH, D. W. FISHLER, M. H. BYROM
and R. V. ALLISON[2]

Production of kenaf fiber by water retting, aerobic retting (mist), and stack retting are discussed; and data on fiber quality as influenced by retting methods are given. In a previous report,[3] yarns made from stack-retted and water-retted fiber were compared. It was shown that water-retted fiber produced a satisfactory yarn and that stack-retted fiber did not.

AEROBICALLY RETTED FIBER, 1956

Fiber aerobically retted in 1956 was subsequently spun into yarn. The mill evaluation of this fiber, and a companion lot of water-retted fiber was as follows: "The fiber processed without any particular difficulty. The waste loss was 2½ percent higher than jute." The yarns were later woven into carpet backing and no differences were noted in the weaving of the two yarns. There was no discernible difference in appearance of the yarns from the water-retted and mist-retted fiber (Figure 1).

STEM DISEASES AND AEROBIC (MIST) RETTING.

In 1955 ribbons from diseased stems did not ret well in the moist chamber. However, few disease lesions developed on the stalks in 1956, and a good fiber was produced. During 1957 stem lesions were very prevalent on kenaf grown on the organic soil at Belle Glade. Figure 2 illustrates the degree to which diseased spots on ribbons increased in the moist chamber in "mist retting" as compared to the containment of the diseased areas on the ribbons retted in water. The fiber from these mist-retted ribbons was stiff, discolored and poor in tensile strength.

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[1]Research work on which this report is based was conducted cooperatively by the Crops Research Division and Agricultural Engineering Division, Agricultural Research Service, U. S. Department of Agriculture and the Everglades Experiment Station of the University of Florida Agricultural Experiment Station, Belle Glade, Florida.

[2]Plant Pathologist, Agricultural Research Service, U. S. Department of Agriculture; Agricultural Engineer, Everglades Experiment Station, University of Florida Agricultural Experiment Station; Agronomist and Agricultural Engineer, respectively, Agricultural Research Service, U. S. Department of Agriculture; and Fiber Technologist, Everglades Experiment Station, University of Florida Experiment Station, Belle Glade, Florida.

[3]Summers, T. E., J. W. Randolph, M. H. Byrom and R. V. Allison. 1956. Progress Report on retting kenaf and jute ribbons. Proceedings, Soil and Crop Science Society of Florida, 16: 307-313.

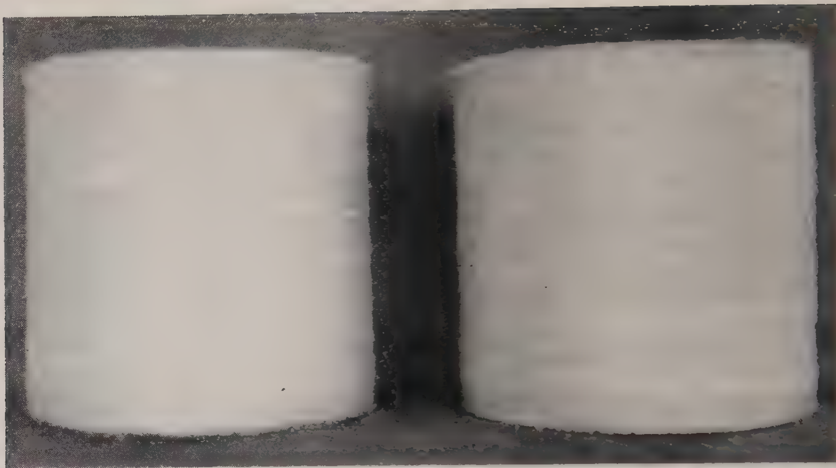


Figure 1.—Yarn (No. 14) from aerobically (mist) retted fiber (left) and from tank-retted fiber (right) as put up in 10-pound spools.

RETTING IN SURFACE CANALS.

The 1956 report mentioned that kenaf fiber retted well and in a short period in the surface canals at the Everglades Experiment Station *if* the ribbons were kept near the surface of the water and were not excessively compacted or weighted to the bottom of the canal. The tensile strength of canal-retted-fiber consistently exceeded that of fiber from comparable ribbons mist-retted or retted in large concrete tanks (Table 1).

Obviously, the mist-retted and stack-retted fiber was much inferior in uniformity of strength to the water-retted fiber, whether retted in canals or tanks.

An improvised method of suspending ribbons in the canal so that they floated loosely beneath the surface of the water is illustrated in Figure 3. Weights consisting of iron rails were placed on the bottom of a canal in which the water had been lowered, loops made of rope were attached to the rails, and the ends of poles on which kenaf ribbons had been placed (as they were produced by the ribboner) were inserted through the loops and the water returned to a level at which the ribbons were covered. The distance from the bottom (or top) of the canal, at which the ribbons were suspended, could then be easily

TABLE 1.—SOME STRENGTH COMPARISONS OF KENAF FIBER RETTED BY DIFFERENT METHODS FROM COMPARABLE LOTS OF RIBBONS. (STRENGTH TO BREAK IN PSI (½INCH BREAK) IN 1000 POUNDS.)

Method	1955	1956	1957	Range in breaking strength
Tank	38.5	32.7	34.3	26.3 - 46.0
Mist	28.8	37.0	34.5	13.2 - 49.9
Canal	-----	36.2	42.6	22.4 - 64.5
Stack	18.0	23.7	-----	11.1 - 40.5

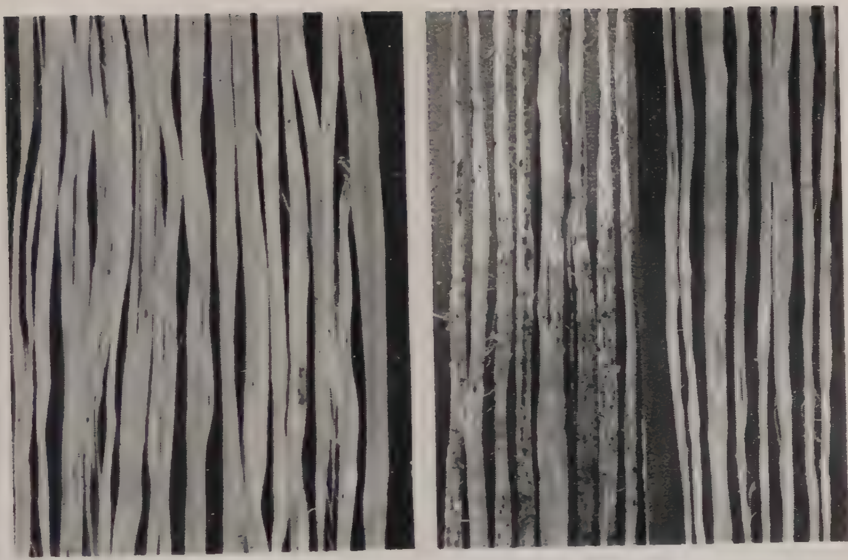


Figure 2.—1, fresh ribbons from diseased stems. 2, left, ribbons held in moist chamber 24 hours; right, ribbons held in water 24 hours.

controlled. For good fiber color and luster it is important that the water be clean and free from excessive silt and other discoloring matter. Silt should be removed from the canal or care should be taken not to disturb the sediment when placing the ribbons in it or while removing them from it.

Note: During the past four years the cooperative work between the U. S. Department of Agriculture and the Everglades Experiment Station at Belle Glade on kenaf as a substitute for jute has been greatly benefitted by the splendid assistance extended by four of our principal jute spinning mills: Schlichter Jute Cordage Company and Linen Thread Company in 1955, on water and stack-retted kenaf; Schlichter in 1956 on water-retted and mist-retted fiber; Revonah Spinning Mills in 1957 on water-retted and mist-retted material and Schlichter in 1958 on water-retted kenaf. In the last-named test, for the first time, a good No. 9 yarn was spun which, as this Proceedings goes to press, is under test by the Corps of Engineers, U. S. Army, at its Ft. Belvoir laboratories for use in camouflage cloth which was woven in a 9 oz. (sq. yd.) weight for these tests by Hazelhurst Mills, Hazelhurst, Georgia. In this test Schlichter also produced an excellent No. 14 yarn from water retted kenaf fiber which also was woven into a rather open, 9 oz. fabric for testing by the Corps of Engineers. The fiber in both of these fabrics is also undergoing extensive weathering and protective treatment tests by a Chicago firm that should be completed and the results available by the time of the next report.

The principal effort on all the above spinning tests has been the production of a No. 14 tying cord satisfactory for use in the U. S. Post Office. While its strength consistently has been found a bit low in all samples made available to date, encouragement has been received from two large post offices where official trials were made to the effect that this fiber has been much more satisfactory than standard jute sources, especially for those workers troubled in one way or another by dust in the air. If there is a difference in the dust content of these two widely different fiber sources (Pakistan and Florida), which doubtless has to do with methods of processing, this is understandable since the snapping of the twine with the hands in normal use in the tying of packages is so close to the face and, in fact more or less right beneath the nostrils of the worker. Practical trials with the No. 14 tying twine from the 1957 fiber supply are being continued.—Ed.

Figure 3.—A, placing rails in canal; B, loops attached to rails; C, placing ribbons in canal; D, ribbons beneath surface of water, Everglades Experiment Station, Belle Glade, Florida

Kenaf Fiber Grading

E. S. Boote[1]

The efficient grading of fiber *before marketing* is fundamental in several important aspects; viz. to assure the following:

a) The accurate determination and classification of fiber characteristics under grade marks, or names. Such identification is as necessary to the fiber buyer as the make and model are to a buyer of a motor car.
b) Uniformity, by grouping fiber of similar characteristics. Without grading it is impossible to provide the grade regularity, hence the dependability on which the reputation of the fiber in the market place largely depends.
c) The determination of a price fair to both buyer and seller. To attempt to establish a price without known regular grades is to prepare for confusion, claims, and dissatisfaction so costly to buyer and seller alike.
d) The proper utilization by the manufacturer. The quality and regularity of the manufacturer's product are built very considerably on the care with which the fiber is graded before it reaches him. Corrective regrading is very expensive.

In view of these facts the proper grading by the seller or producer is only a matter of business common sense yet, where fiber origins are separated from consuming centers by thousands of miles, and where buyers and sellers do not understand, or choose to disregard these necessities, the truth of the benefits of consistent grading tends to become obscured.

The cost of grading is a fully justified part of the preparation of the fiber along with the expense of the agricultural processes, retting or decortication, and baling.

Grades are best represented by standard samples supplemented by a written description of what each sample grade is intended to represent. This is particularly important in bast fibers such as kenaf, jute, and true hemp (Cannabis sativa) where the long fiber strands make it more difficult to reflect in physical samples, the permissable variation of characteristics within each grade, than in the shorter fibers such as cotton, coir, and wool.

When a new mark of jute is to be marketed, sellers usually make sample bales available to the trade through their agents, after having issued a brochure or circular setting forth the mark or identification of the proposed grade, together with a description as to fiber type, strength, fineness, cleanliness, color, and length.

To establish the standard of a grade, there need be a full exchange

[1]Vice President, Ludlow Manufacturing and Sales Company, Needham Heights, Mass.

of ideas and requirements between the producer or his agent, and the buyer. Where direct contact between producer and user is possible, the preparation of acceptable standards is expedited. In long established fibers as jute, cotton, and wool, basic groundwork in determination of grades has long ago been accomplished (in wool and particularly in cotton, Government Agriculture Departments have played a very important part in promulgating standards.) It is, of course, necessary to keep fiber standards up to date in terms of changing agricultural methods and results, manufacturer's customers needs, and machinery developments. One good method of accomplishing this is by means of reports from the buyer to the seller or his agent, on each lot as soon as possible after delivery, the report to set forth in detail all variations from the agreed standard.

Having built up somewhat of a general background we can now be more specific in the discussion of possible grades for kenaf. The manner of describing jute characteristics offers a ready made yardstick, particularly helpful because of the problems resolved in marketing many billions of pounds of this fiber during the past one hundred years and more.

The principal characteristics of jute which are considered in determining the grade are:

Type Is the fiber White Jute, Tossa, Daisee, Meshta (Cannabinus), or Bimli (Sabdariffa altissima (roselle))

Strength Is the fiber very strong, strong, tender or partially weak, weak, or perished?

Quality (Fineness) Is the fiber fine, medium, or coarse and is it "heavy in the hand," i.e. of high, medium, or low density?

Cleanliness Is the fiber clean or does it contain varying degrees of blemish such as speck, leaf, and unretted portions, namely hard bark of varying length, and root?

Color Is the fiber light or dark, or somewhere in between?

Length Is the fiber long, medium, or short?

Ends Are the top and root ends clean or blemished, and are the top ends weak?

Condition Is the fiber in fair merchantable "condition" i.e. moisture content?

Detailing these characteristics further and applying them to kenaf, where possible, it can be said:

TYPE

Fiber type need not be pertinent to kenaf grading at present.

STRENGTH

The American market for jute yarns is essentially a warp yarn market, i.e., one in which the yarns used are as warp in weaving, as yarns in manufacture of electric cables, as twines, etc. Strength is of paramount importance to the warp spinner. The choice of soil on which the fiber is grown is important because rapid growth and

maximum strength have not been found compatible. Strength moreover, or the lack of it, is largely a function of the ret, assuming the same type fiber. Under-retting tends to produce stronger fiber but more difficult to clean, while over-retting, by eliminating more of the binding substances or pectins, tends to produce weaker but more easily cleaned fiber. The skill in stopping the ret when the optimum point is reached between good strength and the ease of cleaning is basically of first importance, the lack of which certainly would result in failure to provide suitable fiber for the warp spinner's purposes.

QUALITY (Fineness)

Whether the fiber is coarse, medium, or fine, depends on several factors, among them the size of the stalk, the maturity of the plant when harvested, and the extent of the ret. The finer the fiber (fine fiber weighs less per given length than coarse fiber), the finer the yarn that can be efficiently spun from it. In kenaf, jute, and true hemp, a stalk the thickness of a lead pencil at harvesting time is thought to give the best balance between fiber yield and quality, presuming, of course, proper retting. The number of plants per acre is the principal control of the size of the individual stalk. It is also beneficial to harvest when the stalk has reached fiber maturity and to avoid either immaturity or overmaturity. At times it is difficult to convince a grower that the larger per acre fiber tonnage resulting from delayed harvesting, does not necessarily mean a larger per acre value. It is generally accepted that a smaller per acre tonnage of mature, good quality fiber produces more revenue than a higher per acre tonnage of overmature, hence lower quality fiber. However, when the grower is paid for tonnage without proper evaluation of quality of that tonnage, control of fiber fineness through harvesting at the proper time is difficult.

CLEANLINESS

The value of fiber to the spinner is severely reduced by blemish which increases waste, reduces the efficiency of the spinning and winding operations, and makes a less valuable end-product. Blemish includes speck, generally the result of branching, insect bites, or disease, and hard bark due to poor retting. Since the chemistry and structure of the stalk indicate less time needed for properly retting the top than the root of the plant, the top is generally found to be somewhat over-retted and hence, weaker, and the bottom almost invariably under-retted, thus leaving hard bark or root which is cut off during the grading process. Usually, therefore, the middle portion containing the preponderance of the weight of the stalk, is correctly retted, hence, reasonably clean.

COLOR

The color of retted fiber is basically the purity of the steeping water. Oft-used steeping water produces darker color, though of course, the pigmentation of the fiber is an important factor as well.

Light color, the whiter the better, is taken by the average consumer to mean higher quality and performance, though this is not always true, for some very dark fiber is stronger than some very light fiber. Cloth of light color is preferred because it shows off color printing much better than a darker cloth.

LENGTH

Length of itself is relatively unimportant, but as an indication of quality is significant. On the average, jute which in the bale after grading and cutting is over 7 to 8 feet in length, tends to be coarse from overmaturity and lacks weight, i.e. density. At the other extreme, immature jute, less than 3 to 4 feet, is apt to be underdeveloped, and hence difficult to ret and to clean, but may be very weighty. Fiber which, due to favorable growing conditions, reaches a length of 8 to 10 feet without becoming overmature, and which is properly retted in clean water, is considered to be top quality, being strong, weighty, of medium fineness, clean, light colored, and long.

The mixing of jute of varying lengths in the same bale or piece, complicates handling, increases wastage, and is considered evidence of poor control of the grading operation.

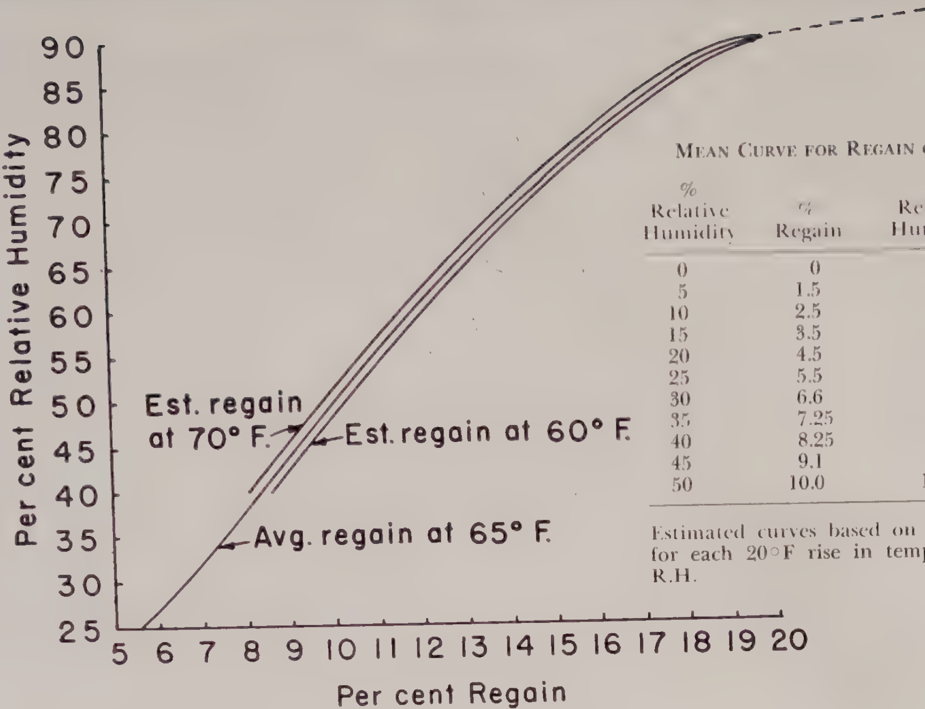
CONDITION

Moisture content is one of the most difficult phases of the marketing of bast fiber to control and adjudicate. Fiber containing excess moisture deteriorates in strength, and occasionally in color. The greater the moisture, ordinarily the more rapid the spoilage. From the buyer's standpoint moreover, it is a very serious matter to pay for water at the price of the fiber.

If the drying process after retting is allowed to continue to the point where only the natural moisture content remains under the conditions of temperature and humidity at time and place of drying, the producer can be assured that his customer can have no valid complaint. Since, however, there inevitably will be differences of opinion, agreed methods for testing for moisture should be set up. One method of using the results of such tests is to make allowance to the seller for lower than the agreed moisture content, and to the buyer for excess over the agreed moisture content. The agreed acceptable moisture content should be noted in the contract covering the sale.

The normal moisture content of jute at 70 per cent relative humidity and 65° Fahrenheit, is 13¾ per cent. Recognizing the necessity of some variation, some buyers and sellers consider 17 per cent moisture content over the dry weight of the fiber as being equitable; however, the concept of fair moisture content varies according to trade opinion and custom in various parts of the jute buying world.

The jute grading nomenclature is quite complicated due to the long time over which these grades have been evolved, differing requirements of many widely separate spinner customs, and the complexity of jute fiber type variations.



MEAN CURVE FOR REGAIN OF JUTE AT 65° F

% Relative Humidity	% Regain	% Relative Humidity	% Regain
0	0		
5	1.5	55	10.75
10	2.5	60	11.75
15	3.5	65	12.80
20	4.5	70	13.75
25	5.5	75	15.0
30	6.6	80	16.5
35	7.25	85	17.5
40	8.25	90	20.0
45	9.1	95	24.5
50	10.0	100	27.0

Estimated curves based on 1% drop on Regain for each 20°F rise in temperature at constant R.H.

EXHIBIT NO. 1—CURVE FOR REGAIN OF JUTE

Mean curve at 65° F from "The Moisture Relationships of Jute," I.J.M.A., Calcutta, Feb. 1939, p. 34. Estimated curves based on "Moisture Regain of Jute etc." Ind. Cert. Jute Com. Tech. Res. Mem. No. 3, Mar. '41, p. 5.

The principal types of jute fiber are:

In Pakistan

White jute
Tossa or Brown Jute
Meshta

In India

White Jute
Tossa or Brown Jute
Daisee
Meshta
Bimli

Since India at present allows no jute to be exported, reference from this point on will be only to Pakistan jute export grades.

The Pakistan White Jute and Tossa are further subdivided into:

Jat or Dacca, i.e., the highest class.
District, i.e., medium class.
Northern, i.e., lower class.

The grade designations in each of these classes have gradually been developed over decades of business, the original and full significance of many of the terms having been lost. Cuttings are a separate classification.

Dacca, District, and Northern White Jute, in descending order of quality and price, are designated as: Dundee Firsts, Dundee Lightnings, Dundee Hearts, Mill Firsts, Shipment Firsts, Shipment Lightnings, and Shipment Hearts. There are several synonyms for most of these grades, for instance—Shipment Firsts are also referred to as "Export Firsts" or as "LJA Firsts."

Dacca Tossa, in similarly descending order comprises the following grades: Dacca Tossa 2 3, Dacca Tossa 4, Dacca Tossa 5, and Dacca Tossa 6.

Further, District and Northern Tossa comprise: Short Group Tossa 2 3, Short Group Tossa 4, Full Group (or Dundee) Tossa 2 3, Full Group (or Dundee) Tossa 4, Outport Tossa 2 3, and Outport Tossa 4.

At this point slides of the Indian and Pakistan jute sequence were shown and samples of some of the export jute grades exhibited and discussed.

Considering kenaf as representing only one fiber type practically speaking, no such complex nomenclature as just described for jute need be undertaken for it. Let us then, first consider a plan for retted kenaf grades. Such a plan can most effectively be based on the five fundamental fiber characteristics of strength, quality or fineness, cleanliness, color, and length.

In the initial stages of developing grades for retted kenaf, I envisage only three, namely, "Good," "Medium," and "Poor." The highest classification, or "Good," would contain only fiber which is unquestionably strong, mostly fine, clean, regularly light in color,

EXHIBIT NO. 2

Suggested Grade Specifications for Retted Kenaf

Kenaf Grade Name: Initial Grade	Kenaf Grade Name: Eventual Possibility	Strength	Quality (Fineness)	Cleanliness	Color	Length
Retted Good	Retted Superior	Very strong	Heavy, flexible, and mostly fine	Clean	Light, regular	Over 4 feet
Retted Good	Retted Good	Strong	Fine to medium	Clean	Light, regular	Over 4 feet
Retted Medium	Retted Medium	Strong	Medium to medium coarse	Minor blemish	Some irregularity Light to medium	Over 4 feet
Retted Poor	Retted Fair	Strong to questionable	Fine to coarse May lack weight	Moderate blemish	Irregular Light to gray	Over 3 feet
Retted Poor	Retted Poor	Strong to weak	Fine to coarse May lack weight	Heavy blemish	Very irregular Light to dark	Over 3 feet

and in length not less than 4 feet. The lowest or "Poor" grade would accommodate heavy to moderate blemish, all degrees of strength, fine to coarse quality, irregular in color, light to dark, and any length of over 3 feet. The middle or "Medium" grade would comprise the remainder of the fiber not good enough for the highest classification and not low enough for the "Poor" division.

Spinners' needs might well eventually require a further refinement which could be accomplished by dividing the "Good" into "Superior" and "Good," and the "Poor" grade into "Fair" and "Poor," thus providing five grades, namely, 'Superior," "Good," "Medium," "Fair," and "Poor." Exhibit No. 2 presents full details and fiber samples are available further to illustrate them.

It is suggested that the grading plan should be finalized only after as large a group of producers and users as practicable were consulted.

It is important that each bale of fiber be plainly marked with a bale ticket or marker with a design and color the same for the entire Industry to facilitate ready identification wherever used.

Some liaison in inspection of grades at producing centers should be set up either by the Industry or by appropriate Government Agency to assure regularity of grading.

Finally, I want to express appreciation for the opportunity of taking part in this Conference and to stress what a golden opportunity I think the Kenaf Industry has to start in the right way by standardizing on grades and procedures that will help to make this fiber a welcome addition to the world fiber family.

Kenaf Fiber Quality[1]

E. G. Nelson[2] and R. V. Allison[2]

Grading factors, which Mr. Boote has discussed in the immediately previous paper, are based on the experience of manufacturers, supplemented by laboratory determinations. The factors that are now to be discussed are those that need to be studied in a laboratory, not only for grading considerations but especially for the development of kenaf as a crop.

Specifically, these are strength, fineness, and flex life.

It is fortunate that kenaf has so much in common with a fiber like jute which is so well known and so widely used. For, in talking about kenaf, it gives us something for comparison. It should be kept in mind, however, that jute is used in enormous quantities because it is so well adapted in general—not because it is strong compared to other fibers. Although jute does have about as low a breaking strength as any fiber in international trade, standards have been established that require any substitute fiber to be almost as strong as jute itself for most uses.

Many conflicting statements have been made about the relative strength of kenaf and jute, and the products made from them. It is generally agreed among manufacturers, however, that jute is slightly stronger than kenaf. The difference is slight. If it were not slight, laboratory tests would not be so conflicting.

In our laboratory, we have tested hundreds of samples of kenaf, representing various lots of experimental material, and numerous samples of imported jute fiber, representing a wide range of grades. Our results have shown that, on the average, kenaf has more than 90 per cent of the strength of jute. Results from some laboratories have indicated the opposite, but I have a lot of confidence in our results. What is more, they have been backed up by other research workers. We cannot use an exact figure to compare the two fibers since the samples tested were from different sources. I hope soon to have such a figure from plot material designed to give exact comparisons under several different growing conditions.

I'm scheduled to discuss kenaf's tensile strength. And certainly the strength of kenaf and jute fiber has come in for a good deal of attention. But fineness is a factor that cannot be overlooked. In this, the two fibers differ perhaps more widely than in any other way. All tests and opinions that I have seen reported agree that kenaf is not as fine as jute. That is a defect in kenaf. Tests in our laboratory have shown that a single jute fiber a meter long weighs about 2 milligrams and a kenaf fiber the same length weighs about 3¼ to 4 milligrams and

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[1]First presented at the International Kenaf Conference, October 27-31, 1958, Havana, Cuba.

[2]Agronomist, USDA-ARS, Crops Research Division, Beltsville, Md. and Fiber Technologist, Everglades Experiment Station, Belle Glade, Florida.

grams. Fineness depends, of course, not only on the inherent qualities of the plant from which the fiber is taken but also on the kind of soil, the density of the stand, the age of the plant when harvested, the amount of retting, and the method of stripping and washing. Thus, fineness can be controlled within the limits of the species or variety. But care must be exercised. Yields may be reduced by too dense a stand or by harvesting too early. Over-retting to gain fineness may ruin the fiber by loss of strength. And the fiber itself may be lost by too severe treatment in processing. By using the means we have and by exercising care and good judgment, a highly acceptable product can be produced.

Fortunately, the main uses being considered for kenaf in Latin America do not require the fineness of fiber necessary for the warp spinners in the United States. An excellent quality bag can be made from a fiber that is too coarse to be of interest to the maunfacturers of carpet yarn. But even the manufacturers of coarse yarn will have less trouble in spinning if the fiber is moderately well separated. The few tests we have made on the fineness of decorticated fiber show that the strands were about twice the size of retted kenaf. This, of course, applies only to the samples we tested. Material prepared by different methods would not necessarily be in the same range of size.

In literature on kenaf, coarseness is often associated with brittleness. It is not known, however, whether a coarse fiber is necessarily a brittle one. But some of our tests have indicated that kenaf is more brittle than jute. In these tests, we run a bundle of fiber about the size of a binder twine over small pulleys until the bundle breaks. Kenaf has averaged about 1,100 cycles; white jute has averaged 1,900; and tossa, 2,200. We are not sure what this means in terms of finished product, but it is an indication.

Another test that may be an indicator of brittleness shows no difference in the two fibers. This one is on knot strength, and shows that jute and kenaf have the same breaking strength in the knot.

You will notice from my remarks that jute has a slight edge over kenaf in over-all quality. And I believe we should not overlook jute as a potential in some highly favorable areas in this Hemisphere. But kenaf is much better adapted in most locations, and the fiber is almost as good. It is grown in India on about a quarter of the acreage devoted to the two crops, and it is used in the manufacture of their burlap. (It is not grown in Pakistan.) In the United States, tests have shown it to be satisfactory for post office twine and sandbags. Under actual shipping tests with Cuban sugar, kenaf held up as well as imported jute bags. In Mexico, kenaf is being used commercially for the manufacture of a strong, light-weight burlap.

In commercial products, we can of course expect a wide range of quality. Some of the fiber will be satisfactory only for heavy sacks. But proper sorting and grading should yield some fiber of a quality good enough for carpet yarn.

In summary, evidence seems to point to the fact that kenaf is slightly weaker, coarser, and probably more brittle than jute. But it is the best substitute we have, and we know we can produce it in this hemisphere.

In the past, our efforts have been directed toward producing kenaf with disease resistance and high output. From now on, however, it is obvious that researchers have the responsibility not only of maintaining production levels but also improvement of quality. The potential is enormous.

THE SPINNING OF UNRETTED KENAF RIBBONS FROM THE VIEWPOINT OF:

THE EQUIPMENT MANUFACTURER

A—James Mackie & Sons Belfast, Ireland[1]

We wish to thank the Soil and Crop Science Society for the opportunity to say a few words here about the spinning of unretted ribbons from the viewpoint of machinery manufacturers.

Already in Havana we said that our machines can spin unretted kenaf ribbons without difficulty into 24 lbs. yarn if the ribbons are harvested in reasonable ripeness for fiber and if they are free of weeds, mainly of morning glory which f. e. in Veracruz State could not yet be fought successfully.

For unretted ribbons we have to give more softening and more fermentation in the preparation for spinning than is needed by retted fiber. Preston's new harvester-decorticator may make this slightly easier.

The excellent study of Stanford Research Institute in kenaf 1957 calculated under Cuban wages that unretted ribbons could be delivered to the spinning mill for 5 cts lb. equal to 12½ cts for a sugar sack of 2½ lbs. weight. The manufacturing costs from softening to sack sewing inclusive with capital costs on stockpiling ribbons and sacks till needed we estimate 17½ cts per sack, making a total of 30 cts per sack.

Unfortunately the Stanford workers have not been informed by the machinemaker whom they visited that this processing of unretted ribbons with all the bark on the outside gives, on the average, about 15 per cent loss of weight in spite of the added oil. These 15 per cent make about 2 cts sack more raw material costs with the unfavorable effect that the sugar sack made in Cuba from unretted ribbons will cost about 2 or 3 cents over the price of Pakistan or Calcutta Twill or Heavy Cee. Thus we cannot recommend the so-called coarse process for Cuba.

In *Salvador* we have studied the situation since the Havana meeting. As most of you know, Mr. Dalton has successfully made coffee sacks out of kenaf ribbons. One of his sacks is exhibited here and its brownish color indicates that the kenaf stalks or ribbons received a series of rains which, to a certain extent, made them dew-retted or semi-retted, a fact that facilitates spinning.

But apart from this any machinery can keep going in Salvador as the price of the 2 lb sack is around 60 to 65 cts. The only competitor for Dalton's sack is the sisal sack of the Cuscatlan Mill, using our

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[1]By: Dr. Henry Schneider, Consultant, Voltastrasse 1, Zurich, Switzerland.

gillspinners. If this firm would reduce their price considerably it would become more difficult for the sack made from kenaf ribbons.

In *Guatemala* the protection against Pakistan and Indian sacks is even higher than in Salvador. In addition to the already existing 2 mills making sisal sacks for coffee there is now about to start up a still bigger sisal sack mill with our newest machinery. All 3 mills together can produce 2 million sacks per annum thus will cover the normal yearly demand for heavy sacks in Guatemala.

The Stanford research study states, on page 124, that in Guatemala a kenaf coffee bag mill for 2½ million coffee bags is to be erected in the near future by a group of American and Guatemalan investors.

The controversy about the price of unretted ribbons which the future Guatemala spinning mill would have to pay, namely 2½ or 6 or 8 cts per pound of clean dry ribbons, can be left aside as long as the present price of 70 to 75 cts for a coffee sack of 2 lbs weight in Guatemala remains.

But the project of producing additional 2½ million heavy sacks in Guatemala we consider wrong. What should the country do with 4 or 4½ million heavy sacks?

We therefore proposed that the projected new mill in Guatemala should be based on *retted* kenaf fiber which would permit the manufacture of lighter sacks of one lb average weight for salt, for flour, corn, wheat, beans, etc.

The smallest economic unit from retted fiber as well as from unretted ribbons would give in each working hour 600 lbs weight sackcloth. In the case of unretted ribbons this means 300 sacks of 2 lbs weight while with retted fiber it means 600 sacks of average 1 lb weight.

Comparing both installations I may say that from retted kenaf fiber with 1/3 more labor and 2/3 more machinery investment can be made 100 per cent more sacks. In case of an extraordinary high coffee crop a quantity of these light sacks can be used for coffee export as all Brazilian coffee is exported in light sacks from retted, Brazilian fiber.

Our proposition of a mill for light sacks from retted kenaf should be studied in Guatemala all the more carefully as the promoters ask financial help from U. S. Governmental funds and such funds should not be lost by wrong investments.

If you can make from retted fiber with 1/3 more labor and 2/3 more machinery investment three third equal 100 per cent more sacks it is obvious that this is more economical than making sacks from unretted ribbons.

It is also more satisfactory from the agricultural point of view. In spite of the 33 per cent loss in retting compared with the 15 per cent processing loss in case of unretted ribbons you make from the yield of one acre via retted fiber about 70 per cent more sacks; from 1 acre nearly 3000 sacks averaging 1 lb in weight compared to about 1800 sacks of 2 lbs weight from unretted ribbons.

The so-called "coarse" process seemed to be a suitable solution for making sugar sacks in Cuba but they would be more costly than the sugar sacks from India and Pakistan which are made mainly from

the waste of the big mills, holding it together by a portion of long jute. It would be wrong to replace these materials, which fully serve the purpose, by good kenaf ribbons which by retting can be made into much more valuable sacks.

Of course the controlled warm water retting in canals with countercurrent brings the price of the fiber to say 11 or 12 cts per lb. But in a sack of average 1 lb weight these 11-12 cts plus about 1/3 ct processing loss make 11½-12½ cts raw material cost per average sack. And these are only little higher than 2 lbs ribbons plus 15 per cent processing loss equals 2.30 lbs x 5 cts equals 11.5 cts or more if the mill must pay more than 5 cts lb for the unretted ribbons which can make only coffee sacks, whilst retted fiber can make sacks for many purposes.

In *Mexico* the coffee sacks are made from either sisal or in the last few years more and more from the yucca sprouts of the so-called palma samandoca which, on our latest machinery, makes excellent sacks.

The few kenaf promoters in Mexico therefore were wise in never trying to compete with unretted ribbons against sisal or palma ixtle.

They have right from their first kenaf fields built retting installations and get about 14 cts/lb for their retted fiber.

Beyond any doubt for making the most economic use of kenaf the retting is the best way. Therefore the efforts in this hemisphere should now be concentrated on industrial retting. For this we wish best success and also offer our experience in retting to those who may desire it.

B—Fairbairn Lawson Combe Barbour, Ltd., Leeds, England[1]

It is perhaps important, in the first place, to differentiate between the technical and commercial aspects of the utilization of kenaf fibre.

From the technical stand-point, the principal fact of importance is that modern jute machinery made by any reputable manufacturer is suitable for the processing of retted or un-retted kenaf fibre. The exact specifications of some of the machines will vary according to which type of kenaf fibre is employed because the spinning qualities of these two categories differ appreciably—but these variations are of minor importance at the present juncture.

From the commercial stand-point the possibilities of establishing a successful kenaf sack factory will obviously vary quite considerably according to the conditions obtaining in the country under consideration. Of these conditions, the principal ones are the ruling labour costs and whether or not the sacks to be made from kenaf must withstand direct competition, in regard to price, from jute (or other) sacks at present made in, or imported into that country.

In recent years the attention of all whose interests are allied to the development of kenaf has been focussed upon Cuba—the reasons being, no doubt, the favourable conditions existing there for the growing of kenaf and the proximity of Cuba to the U.S.A.

The conditions there which govern the establishment of a successful sack factory are however singularly unfavourable. Labour costs are high and the sacks to be made would have to withstand direct competition with those now imported from Calcutta.

As you well know, the vast majority of these sacks are required for the transportation of sugar—a relatively cheap commodity sold in the world markets under conditions of intense competition. It is thus highly problematical whether the sugar growers could be induced, under any circumstances, to pay more for the sacks they require, than the ruling prices for suitable sacks made in Calcutta.

As the economy of the country is founded on the growing of sugar, no Government would conceivably be so imprudent as to enforce the payment of higher sack prices for the sole purpose of fostering a kenaf growing and processing industry.

In our opinion, the foregoing conditions virtually eliminate the possible use in Cuba of retted kenaf fibre for the manufacture of sugar bags. The use of un-retted kenaf however would permit the manufacture of sugar sacks at a *cost* reasonably close to the prices at which imported jute bags are available. Whether or not a profit margin

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[1]Note—Representatives of Fairbairn Lawson Combe Barbour Ltd., were unfortunately unable to attend the Florida meeting. However, the above comments were prepared upon request and have since been received from them regarding both the utilization of kenaf in the Caribbean area and some of the statements made in this connection in the course of the St. Petersburg conference. Correspondence in this matter has been with Mr. H. G. Tomkinson, for the company.—Ed.

would exist is doubtful and in consequence, the attractiveness of such a venture to private capital is negligible.

We think that any project to utilize kenaf (retted or un-retted) in Cuba should be directed initially towards the manufacture of sacks and cloth for users other than the sugar industry e.g. coffee, rice, beans etc. Even so, it would require, at the outset, Government assistance either in the form of a subsidy or of a protective tariff. It is perhaps reasonable to assume that, once an infant industry is established, the growing of kenaf on a larger scale and possible improvements in the methods of decortication resulting from practical experience, would result in some reduction in the cost of the raw fibre thus reducing the necessity of Government assistance to the processing industry.

Because of the lower cost of un-retted kenaf say 5 cents lb. as compared with 12 to 14 cents lb. for the retted fibre—we regard the utilization of it in this form to have the greater possibilities. This is a commercial and not a technical consideration.

In El Salvador, conditions are radically different from those in Cuba. Labour costs are cheap and the relatively small sack requirements of that country have, until recently, been supplied by one factory which processes henequen and enjoyed for many years a monopoly concession from the Government. This concession expired some five years ago at which time also the mill changed ownership. It was also found at the time that the henequen plantations were diseased on a considerable scale with the result that the importation of henequen from the Dominican Republic became necessary.

Advantage was taken of these circumstances to establish a kenaf sack factory which has since been operated with considerable commercial success. This success results from substantially lower raw material costs—about 3 cents lb. for un-retted kenaf as compared with 7 to 8 cents lb. for henequen (imported or home-grown)—and the strong preference promptly expressed by the coffee-growers for kenaf sacks manufactured from tubular-woven cloth. This preference is such that these sacks command a price premium which,we believe, amounts to 8 cents a bag.

The success of a kenaf sack, in competition with a henequen sack, is in any case a fore-gone conclusion from the point of view of its acceptability to the user. Sisal and henequen are essentially cordage fibres and not weaving fibres despite the appreciable numbers of sisal and henequen sacks manufactured in the Caribbean area.

We agree that the present prices of coffee bags in El Salvador are to some extent artificial and un-realistic but these prices were originally established by the henequen sack factory. If a reduction in them became necessary there is no doubt but that the kenaf sack factory would be in the better position to afford such reductions and still maintain a profit margin—because of the substantial difference in raw material costs.

In Guatemala, the position is similar in so far as labour costs are concerned but the vast majority of the coffee sacks used there are imported jute sacks. Until some three years ago, Heavy Cee sacks from Calcutta were employed but the introduction of an import duty, related to the weight of the sack, resulted in coffee growers using

instead, hessian bags either made in the U.S.A. from imported cloth or manufactured in Europe.

The quantity of sacks at present manufactured in Guatemala is negligible although it will of course be increased when the new factory now being installed enters into operation.

The fibre being used by the two existing small factories and to be used by the new factory being installed is henequen and it is relevant to remark that sufficient fibre is not at present produced in Guatemala to supply total requirements. One of the existing factories frequently employs imported fibre and for the new factory the intention is, as far as we know, to import sisal from the Dominican Republic until such time as new henequen plantations are established in Guatemala.

The establishment there of a kenaf sack factory is, in our opinion, a sound commercial venture. Such sacks will find ready purchasers for the same reasons as have been found in El Salvador. To condemn the establishment of a further factory to manufacture coffee sacks because ample supplies of sacks are already being manufactured is as ridiculous as it would have been to discourage the manufacture of fabrics in the U.S.A. from synthetic fibres because the supply of cotton and other fabrics was already adequate.

The coffee growers in Guatemala are moreover already accustomed to using jute sacks and will strongly resist any attempt to impose upon them the acceptance of henequen sacks.

The view expressed that the projected mill should manufacture hessian bags has a superficial validity and no doubt the proprietors of the new henequen sack factory now being established would warmly welcome such a division of the sack user trade!

Nevertheless, the demand for coffee sacks constitutes the greater part by far of the total sacks consumed and the processing of unretted kenaf is far more attractive, as a commercial proposition, than is the use of retted kenaf—apart from the very considerable capital expenditure involved in the construction of retting tanks, canals, etc. It is perhaps pardonable therefore that the promoters, both in the U.S.A. and in Guatemala, should favour their present project which has received the most careful study during the last two years or so.

At this point it is pertinent to refer to the losses sustained when processing un-retted fibre—which information, it was stated, was withheld from the Stanford Research Institute.

It was said that these losses amount to 15% and this in our opinion is somewhat exaggerated. Losses of this magnitude can perhaps occur when processing fibre obtained from plants harvested at an advanced age but the mill-owners in El Salvador would laugh to scorn any suggestions that the losses experienced there are of this order.

For the sake of accuracy, it should be mentioned that most of the information recorded by the Stanford Research Institute was accumulated by them in Cuba. Any direct approach to our Company was limited to a visit paid here by an economist who was in no way concerned with the technicalities of fibre processing. In consequence, the discussion which took place concerned principally the commercial aspects of utilizing kenaf.

Mention also was made of the use of kenaf in Mexico. The pro-

duction of retted kenaf was commenced near Vera Cruz many years ago. As is known, the plantations recently became infested with Morning Glory with the result that they were abandoned and that land elsewhere is now being employed.

The original reason for producing retted kenaf there was to provide such fibre for employment by two factories which were equipped primarily with jute machinery. At that time these particular mills were using jute, the importation of which has since been prohibited.

The possible use of un-retted kenaf was not then realized but such tests were recently made by one of the factories. Much enthusiasm resulted and the use of un-retted kenaf, as an alternative to palma, is contemplated.

To summarize our views, we would state that the successful establishment of kenaf, as a textile fibre in Latin America, demands that it become available at the lowest possible cost. This is an over-riding commercial consideration and one which will frequently prohibit entirely the use of retted kenaf.

No-one would dispute that the spinning qualities of retted kenaf are superior to those of un-retted kenaf but these superior qualities are un-necessary for the manufacture of sacks as required for the transport of sugar, coffee, beans etc. Retted kenaf is thus a luxury fibre and one whose use the prevailing industrial conditions will not support.

Un-retted kenaf can be available at substantially lower cost and its quality is adequate for the above purposes.

In other words, we are in entire agreement with the statement made recently in Habana by Dr. Claud Horn who said "What is demanded is a *good-enough* quality fibre that is cheap."

THE GROWER

North Atlantic Kenaf Corporation[1]

Again may I say it gives me great pleasure to be here with you this afternoon to help review the viewpoint of the kenaf grower in the production of this fiber crop under Latin American conditions.

I should like to commence my remarks on this subject by saying that the production of Kenaf for spinning & weaving unretted fiber does not present the grower with many new problems. I will not embark upon the technique of the actual spinning process as that subject has been very capably handled by James Mackie and Sons, Ltd.

The prime objective of the grower is to produce the highest quality fiber and naturally at the greatest possible profit.

In Cuba, Latin America, and Africa the unretted fiber may well prove to have its greatest market in heavy duty sacking for Sugar, Coffee, Corn, Cacao, Alpargatas (rope soled shoes), and some types of twine. In the United States the most apparent markets for unretted kenaf are the relatively new and consist primarily of reinforced plastics, non-woven resin-impregnated structures and bagging. The United States is principally an importer of high quality jute fiber and products for such uses as carpet backing, twines, light weight sacking and burlap. Lower quality fiber is also imported. However, the lower quality amounts to less than 10% of total imports and is generally used for automobile padding and cotton bagging products manufactured out of waste sacking and cloth.

It is our feeling that the unretted fiber will eventually find its biggest demand in the fields now consuming waste bagging, okum and the new booming plastic industry. Although unretted Kenaf is not as high a quality as the better grades of retted jute, it will be considerably cheaper as well as possessing the qualities of strength and certain properties that appear very interesting when combined with various resinous structures. The fiber and pith also promise a new fast and easy to grow source of cellulose for the ever expanding paper and container board industry. At this very moment a Latin American Paper Company is studying the possible switch from European pulp to locally produced Kenaf.

Growers for the future U.S. Kenaf market, if they are to capitalize on its vast possibilities, will have to keep in mind that the U.S. buyers are primarily interested in (1) assured quantity, (2) uniform standards of quality, (3) a stable price structure, (4) and of course competitive prices. With these four conditions satisfied, Kenaf as a U.S. Industry should rapidly assume major proportions.

It is hoped that markets will develop in the United States for high quality decorticated fibers that can be spun down to 12, and 14 pound yarns. North Atlantic Kenaf Corporation's principal effort towards

[1]By: Joseph F. Dryer, Jr., Radiocentro 513-514, Havana, Cuba

developing this market has been to develop a field harvester decorticator that will deliver a really clean and decorticated fiber; we believe we are close to achieving this goal. Current tests are producing a fiber capable of being spun into 16 pound yarn.

The producers of unretted fiber for spinning should strive for an open fiber, light in color, fine in texture and clean of woody pith, grass, and morning glory vines. Other almost equally important factors to be considered are the age of the plant and its maturity. A grower should utilize the early, middle, and late maturing seed varieties when staggering his plantings. This will better enable him to keep his harvesting machinery working in the 90 to 120-day old material that the spinning mills prefer and thereby reduce the problems of lignification. The growers should also take advantage of crop rotation and land conservation in order to continue realizing maximum yields and quality.

We are very hopeful that the fine work being carried on by the University of Florida at its Everglades Experiment Station, in cooperation with the U.S. Department of Agriculture, will be continued in view of the significant contributions already made to the Kenaf Industry. The developments that have taken place, and are continuing to take place, are indeed of great value to not only a possible U.S. Kenaf Industry, but also to the United States' Latin neighbors. The mere fact that these developments are helping them become self-sufficient and at the same time are increasing their employment, should be ample justification for the continuance of this program.

THE PROCESSOR

W. A. Dalton, San Salvador, El Salvador, C. A.

San Salvador, El Salvador
December 3, 1958

Att'n: R. V. Allison, Sec'y-Treas.
Soil and Crop Science Society of Florida
Soreno Hotel, St. Petersburg, Florida

HAVING JUST RETURNED REGRET INABILITY ATTEND Stop THANKS KIND LETTER Stop REST ASSURED SPINNING KENAF RIBBONS PRESENTS NO SPECIAL PROBLEM ON STANDARD JUTE EQUIPMENT BETTER RIBBONS MAKING FOR HIGHER MILL EFFICIENCY WASTE REDUCTION AND FINER COUNTS Stop CRYING NEED IS FOR EFFICIENT HARVESTER RIBBONER Stop BELIEVE (Karl) KAISER'S PRINCIPLE ON CARY PICKUP PROVIDES ANSWER.

Dalton

Note: Doubtless what Mr. Dalton refers to in his message as "Kaiser's principle" is the angled-drum approach to ribboning and decortication of bast fiber plants which apparently was first developed by Mr. Frederick Mertz for the Krupp Company in Germany, in which he was director of the fiber division, right at the close of World War II, in a desperate effort at securing ramie supply for the defense effort even at that late date. This unit was referred to at that time as the "Krupp-Victor." The salvage of the general plan of this machine by the U. S. Government is a matter of record and, seemingly, was first used in building a much too ponderous field unit for ramie harvesting known as the "Siland" decorticator by Sea Island Mills, Inc. As Mr. Dalton has noted, the present application of this approach in the work of Mr. Kaiser (for USDA) in Cuba and of Mr. Preston (for North Atlantic Kenaf Corporation) in Florida is of very great interest and promise especially in connection with the prospects of an improved adaptability of the resulting ribbons to the "Coarse" spinning method. A very preliminary demonstration of the latter machine was made in West Palm Beach on December 5 in the course of a general review of the fiber work in South Florida that followed the close of the St. Petersburg meetings. When kenaf stems nearly 200 days old were supplied this unit by hand-feeding, good ribbons were produced even from such old material with surprisingly little waste.

It is regrettable indeed that Mr. Dalton, with his extensive experience in the spinning of coarse yarns from unretted kenaf ribbons, useful in heavy bag construction, could not be with us. It is doubtful if any other spinner or weaver can equal the volume of his kenaf handling in the processing of batched but unretted kenaf ribbons by what was earlier referred to as the "Trias" and more recently the "Coarse" spinning method, all of which is discussed in considerable detail earlier in this review.

It is particularly unfortunate, of course, that Mr. Dalton could not be present to tell us specifically of the difficulty he experienced in adapting the circular loom to the weaving of the yarns he has produced from unretted kenaf in the past. As this volume of the Proceedings goes to press there is no doubt but that this angle (i.e. the weaving process) has been more extensively discussed by correspondence and otherwise than any other since the time of the meeting. This has been true to the extent that the question has been raised as to the need for carefully reviewing the weaving process, mechanical applications and costs, particularly in relation to the adaptability of flat versus circular looms, as a future symposium on the forum of the Society, perhaps along with a further review of the ribbon processing and spinning angles. Opinions in this regard will be welcomed.—Ed.

BANQUET AND BUSINESS MEETING

The Annual Business Meeting of the Society followed the Monday evening meeting of the first day of the sessions in Hotel Soreno rather than the banquet which was held at the close of the second day. This included most of the routine usually involved including report of an important committee appointed by President Thornton several months earlier to study and report on the adjustment of the annual dues of the Society to more nearly meet the matter of spiraling publication and other costs. This committee was composed of Drs. F. B. Smith, Fred H. Hull and Nathan Gammon, Jr.

The "Passing of the Gavel" followed immediately the exceedingly interesting after-dinner address on Tuesday evening by Dr. J. J. Ochse of Miami on the very appropriate subject "The Economic Importance of Western Hemisphere Agriculture to the U.S.A." By this procedure Dr. P. H. Senn, Vice President for the past year, automatically became president and President Thornton became immediate past president and so replaced Dr. McCloud as a member of the Executive Committee.

The Business Meeting was called to order by President George D. Thornton and the report of the Secretary-Treasurer on membership, finances and publication made the first matter of business. As usual the reading of the minutes of the previous meeting was dispensed with in view of the completeness of the published record in Proceedings Volume 17 (1957).

MEMBERSHIP

During the past year particular effort was made to bring the membership list completely up to date by retiring the cards of all who have not paid their dues thru 1958. This will be repeated in 1959 and, of course, on into the future with the view of preparing for and recognizing such change in dues as is adopted by the Society following report by its committee on this subject in the present session.

In the light of the above the present status of the membership in the Society is more accurately represented in the table below than in any that have been reported before. This has reference, of course,

Geographical Distribution of Membership

	Annual		Sustaining		Honorary Life		Total	
	4/1/58	1/15/59	4/1/58	1/15/59	4/1/58	1/15/59	4/1/58	1/15/59
Florida	568	546	102	94	1	1	671	641
U.S. (other than Fla.)	168	178	43	35	8	7	219	220
Caribbean	109	77	6	6	..	..	115	82
Foreign	37	31	10	8	1	1	48	41
Total	882	832	161	143	10	9	1053	984

particularly to the "annual" category and, as usual, shows the geographical distribution of the three different groups, annual, sustaining and honorary life.

REPORT OF TREASURER

As has been practiced in the past with the approval of the Executive Committee, the financial report of the Society as published is made to cover the calendar year rather than close at the time of any particular annual meeting. This is for the obvious advantages that already have been reported. The report of the Treasurer follows:

Statement of Receipts and Disbursements
January 1, 1958 thru December. 31, 1958

Cash in bank Jan. 1, 1958			
Florida National Bank			$3,083.41
RECEIPTS:			
Regular dues collected		1,255.00	
Sustaining dues collected		2,775.00	
Proceedings sold		140.00	
Donations		30.00	
Postage refunds & other refunds		13.24	
Registration at annual meeting		262.00	
		$4,475.24	4,475.24
Total monies to be accounted for			7,558.65
DISBURSEMENTS:			
Office supplies		36.68	
Postage		290.20	
Refund—Moore-Cottrell		2.00	
Printing—Volume 17		3,278.42	
Bank charges		2.42	
Expenses annual meeting — 1957	9.24		
1958	136.21	145.45	
		3,755.17	3,755.17
Cash in bank 12/31/58			3,803.48
Total monies accounted for			$7,558.65

PUBLICATION

The steady growth in size of the annual Proceedings, taken along with the ever-upward spiraling of publication and other costs, caused the President to appoint a committee quite early in the year to look into the matter of extending the annual dues to an amount which will at least more nearly cover the cost of preparing the annual report for distribution. Proceedings Volume 17 was published by the E. O. Painter Printing Company of DeLand, Florida, in a total of 1320 copies of which 1140 had been distributed by the close of the year.

Copies of earlier volumes of the Proceedings are still available at $1.00 each with the exception of Volumes III and VIII which have been out of print for some time and IV-A which is available only in such a limited number as to suggest they be reserved for those who may want them to complete sets especially in the instance of public libraries.

REPORT OF COMMITTEES

The Committee on Annual Dues:

In the absence of the Chairman, Dr. F. B. Smith, Dr. Nathan Gammon, Jr. reported and moved for the committee on this subject as follows, before the open meeting:

> Your committee to consider an amendment to the By-Laws of the Soil and Crop Science Society of Florida has made a study of the financial reports of the Treasurer and find that the dues currently collected are insufficient to pay the expenses of the Society.
>
> It is recommended that Section 1 of the By-Laws be amended to read: "The annual dues for membership shall be three dollars ($3.00)". This amount is barely sufficient to pay the cost of publication of the Proceedings and it may be necessary to increase dues later. However, the committee feels that dues should be held to a bare minimum of actual operating costs.
>
> Respectfully submitted,

After a comparatively limited and entirely favorable discussion a vote for proper amendment of the by-laws of the Society as moved was called for and the motion carried unanimously.

In consequence of this action By-law No. 1 under the heading of Dues shall henceforth read:

> The annual dues for membership in the Society shall be three dollars ($3.00).

The Nominating Committee:

The nominating committee consisting of Dr. J. R. Neller, Mr. Fred Clark and Dr. Gaylord M. Volk, that had been appointed by the President well in advance of the meeting, recommended Mr. J. R. Henderson, Agronomist in the Agricultural Extension Service of the College of Agriculture, University of Florida, Gainesville, as its candidate for Vice President. There being no nominations from the floor for this, the only elective position in the Society, Chairman Volk of the committee moved that the nominations be closed and the Secretary instructed by the Chairman to cast a unanimous vote for the incumbent. With a prompt second and no questions on the motion Mr. Henderson became the new Vice President.

The Resolutions Committee:

The Resolution of Sympathy read by the Secretary told of the loss by death of nine members of the Society during the year. The reading was followed by a brief period of silence at the request of the President. This resolution is published in full on p. 370 of this volume.

MEETING OF THE EXECUTIVE COMMITTEE

The meeting of the Executive Committee was called to order by President Senn in the lobby of Hotel Soreno immediately following the banquet at the close of which he was invested with this office by retiring President Thornton. All members of the Committee were present.

The first item of business was the reappointment of R. V. Allison, Belle Glade, to serve as Secretary-Treasurer for another year.

Following the usual discussion of time and place of the next meeting and particular subject matter that might be covered, Gainesville, and the campus of the University of Florida, was decided on. The time of the 19th annual meeting was set for during the first week in December on such dates as would not conflict with the holding of the Caribbean Conference, as was done this year. Thus if the Caribbean Conference is to be held on December 3, 4 and 5 the Society would plan to hold its meetings on December 1 and 2 and include Monday, November 30 if need be. However, two days, as has been the usual length, was suggested as adequate. Inasmuch as both meetings will be held this year on the campus of the University of Florida and no travel required from one to the other it will be quite convenient and perhaps even desirable to bring the timing of the two quite close together.

Since Vice President Henderson will serve as Chairman of the Program Committee his ideas of subject matter coverage for the meetings were first sought. His warmest recommendation suggested something of a review of "Two Decades of Soil and Crop Research in Florida." This was well received and an elaboration requested for the next meeting of the Committee.

A second subject that was discussed quite extensively was a symposium on Nematology for which plans had been essentially completed in connection with the 18th Annual Meeting but with insufficient time left for preparation of subject matter. Dr. A. C. Tarjan, Nematologist at the Citrus Experiment Station had very kindly agreed to act as moderator. This subject was regarded as desirable for development at the next meeting as it could fit in well indeed with the general subject of progress with soil and crop research during the past 20 years.

Recognition was given to the opportunity afforded in the development of such a program as has been tentatively decided on of bringing our County Agricultural Agents and other Extension Workers more closely into the work of the Society. Discussion was given to this possibility as a very important one.

The importance of encouraging the preparation of papers on various subjects in the general field covered by the Society by members in industry and others besides our institutional workers was also recognized and quite fully discussed.

RESOLUTION OF SYMPATHY

WHEREAS, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

C. G. Bouis
Leesburg

Harry C. Brown
Clermont

Sam Higginbottom
Babson Park

Charles F. Kettering
Dayton, Ohio

Harold Mowry
Gainesville

John Newhouse
South Bay

E. B. O'Kelley
Jacksonville

Dr. Jose Polak
Mexico, D. F.

Edward F. Wadsworth
West Palm Beach

Allison Senn Thornton

OFFICERS OF THE SOCIETY
1958—Retired

George D. Thornton	President
P. H. Senn	Vice-President
D. E. McCloud	Past President
R. V. Allison	Secretary-Treasurer

REGULAR MEMBERS 1958

Abbott, Fred P., 3019 Warrington St., Jacksonville 5
Acree, Edwin B., Jr., 102 Burns Ave., Springfield, Mass.
Acuna, Julian B., Est. Expt. Agron. Santiago de las Vegas, Habana, Cuba
Ades, Moises, Manzana de Gomez 220, Havana, Cuba
Albritton, E. J., Box 208, Bradenton
Alexander, J. F., Box 157, Bartow
Alexander, Dr. Taylor R., University of Miami, Coral Gables
Allen, Edward J., 2150 N. W. 17th Ave., Miami 42
Allen, Dr. Robert J., Jr., Everglades Experiment Sta., Belle Glade
Allison, Eaves, Box 365, Sarasota
Allison, Dr. Robert V., Everglades Expt. Station, Belle Glade
Allsopp, Ed., Jr., Box 578, Ocala
Alphin, B. W., Box 599, Jacksonville
American Liquid Fertilizer Co., Box 267, Marietta, Ohio
Ancizar, Dr. Jorge, Apartado 18, Bogota, Colombia, S. A.
Anderson, Dr. Myron S., Plant Industry Sta., USDA, Beltsville, Md.
Andreis, J. R., U. S. Sugar Corp., Clewiston
Anduze, F. L., Apartado 1715, Havana, Cuba
App, Dr. Frank, Seabrook Farming Corp., Bridgeton, N. J.
Araneta, Vicente A., 343 Echague, Manila, Philippines
Archbold, J. D., Foxlease Farm, Upperville, Va.
Arey, Wallace J., Box 444, Plymouth
Arkell, William C., Room 3101, 10 E. 40th St., New York 16, N. Y.
Arnall, Frank, Box 919, Ft. Myers
Arrieta, Alberto, 312 Bamboo Rd., Riviera Beach
Asbell, J. E. B., Box 387, Palmetto
Aughtry, Dr. J. D., Box 4906, Memphis, Tenn.
Aycock, William C., Box 38, Lake Park
Ayers, Ed L., State Plant Board, Seagle Bldg., Gainesville
Babcock, F. C., Frick Bldg., Pittsburgh 19, Pa.
Bailey, Bill, Box 216, Belle Glade
Baird, Guy B., Apartado Aereo 58-13, Bogota, Colombia, S. A.
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